INVASION BY MARITIME PINE

IN

ABEL TASMAN NATIONAL PARK

A dissertation presented in partial fulfilment
of the requirements for the Degree of
Bachelor of Forestry Science.

by

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1978

Pine at the Southern Entrance to Abel Tasman
National Park.

"We live in a very explosive world,
and while we may not know where or when
the next outburst will be, we might hope
to find ways of stopping it or at any rate
damping down its force".

Charles S. Elton

"The Ecology of Invasions"

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ABSTRACT

Maritime Pine is one of two species of exotic conifers present in Abel Tasman National Park, in significant numbers. The species was first planted at Bark Bay, (ca.1900) and since then has established itself particularly well, throughout many of the southern coastal areas of the Park. The pines characteristic ecological features make it especially well adapted to colonise many of the infertile and harsh sites that exist in proximity to the Park's coastline and give it a distinct competitive advantage over the indigenous flora of the area. Spread has generally been strongest in a southerly direction, away from Bark Bay, presumably influenced by prevailing winds in addition to suitable sites for colonisation.

The rate of spread of the pine was calculated as 9.1 metres/year, at Bark Bay, away from the assumed initial seed source. It is important to note though, that this rate is considerably increased by the pine's ability to form outliers of pine, significant distances away from the original seed source. The outliers were generally found to be the result of strong winds (greater than Force 6) capable of carrying seed considerable distances, on to sites suitable for colonisation by maritime pine. Consequently this serves to increase the distribution of maritime pine within the Park. This pattern of long-range dispersal has only occurred since ca. 1940 and has only become increasingly prevalent in recent years. At present then, the pine occurs along some 9.2 kilometres of the Park's coastline.

The pine appears to be type specific in its invasion characteristics with low <u>Leptospermum</u> shrubland vegetation types being the most susceptible to invasion. The pine will not usually establish where there is a closed canopy (i.e. Podocarp/Hardwood/Beech vegetation types). Obviously the rate of spread is increasing at an exponential rate as the pine becomes more widespread in its distribution throughout the Park. For this reason a programme of control is recommended, aimed at confining the species to the Bark Bay area, where it initially originated from.

INTRODUCTION

The 22 139 hectare Abel Tasman National Park is essentially a sea coast area deriving many of its unique qualities from its very scenic coastal landforms and vegetation. The formation of the Park, in 1942 saw a park recovering from a century of massive modification. In contrast most National Parks are to all intents and purposes, unmodified by European man which is among the main reasons why they are in fact, National Parks. In Abel Tasman much of the coastline had been left in an extensively modified condition, with the onslaught of European settlers and their burning and clearing operations. Fire had swept through forests and shrublands leaving the area open to invasion by exotic species such as _Pinus_, _Hakea_ and gorse, all introduced by the early settlers. With time decay replaced prosperity, the infertile granite soils led to farms failing and consequently being abandoned, logging and milling died as easily accessible timber was worked out and people gradually deserted the coast.

It seems unusual then that a landscape with such a history of modification should be ever gazetted a national park. The answer is found in the Park's protective legislation (National Parks Act, 1952 and A.T.N.P. By laws, 1954), where in addition to the primary aims of national parks, the Abel Tasman National Park Board which administers the Park is watching over a giant experiment in landscape recovery (Bascands, 1976). With the prevention of fire and other destructive practices it is hoped to preserve indigenous forest. It is with this respect that this study is concerned with just one aspect in this process of landscape recovery.

> That is - "the dynamics of maritime pine (_Pinus pinaster_ Aiton*) and its invasion characteristics in Abel Tasman National Park, as they relate to the natural recovery of the indigenous flora in the area".

This in effect, is just a very small contribution to the knowledge that will be required if we are to acquire an insight into what actually occurs as this land is preserved

* Hereafter referred to as Pine unless otherwise stated.

in perpetuity to allow the indigenous vegetation to recover.

NATURE AND SCOPE OF THE INVESTIGATION

Regarding the unique scenic qualities found in Abel Tasman National Park and the existing presence of several spreading exotic species within the Park, it is important to gain a deeper understanding regarding the ecology of these species. This is especially so with respect to the National Park situation in order to enable optimal management aimed at controlling the spread of these species, as is stipulated in the National Parks Act 1952:

> i.e. "parks shall be preserved as far as possible in their natural state" and that "except where the National Parks Authority otherwise determines, the native flora and fauna shall as far as possible be preserved and introduced flora and fauna shall as far as possible be exterminated".
>
> (National Parks Act, 1952, s.3(2))

Infestations of both *P. pinaster* and *P. radiata* occur within the Park but as only the initial dispersal point of pinaster could be accurately determined, the study was confined to *P. pinaster*. The objectives of the study were then defined as follows:

i) To assess the distribution of *P. pinaster* within Abel Tasman National Park and to determine how this is influenced by both historical factors and prevailing winds.

ii) To determine the rate of spread of *P. pinaster* within the Park.

iii) To briefly study and investigate the plant communities or vegetation associations being actively invaded by pine.

iv) And by using the above and a number of non-quantitative observations to ascertain the threat of the pines spread to the Park.

The study as such was restricted to those areas of the Park where pinaster had actually seeded and grown. From the field survey and reported occurences of the pine, this proved to be the coastal margin of the Park from Tonga Bay in the north to the southern boundary of the Park at Tinline Stream (Map 2). The study involved researching historical records as to when and where pinaster was first introduced into the Park. From this it was deemed that Bark Bay was the first site to have pinaster growing within the present Park boundaries. For this reason the field survey was primarily centered on Bark Bay assuming this to be the centre of origin with dispersal and distribution of pinaster mapped from the Bay.

2. PHYSICAL FEATURES

2.1 Location

Abel Tasman National Park covers an area of some 22 139 hectares in the north of the Nelson province (Map 1) and as such is the smallest National Park in New Zealand. Running almost due north and south (long. 173°E; lat. 41°S) the Park extends from Separation Point in the north to Marahau Inlet at the southern limit (Map 2). The western boundary lies across the highest part of the Takaka Hills, crosses the Wainui River and continues north-east to Separation Point. The Tata Islands in Ligar Bay and Ngaio Island, south of Marahau are also administered by the Abel Tasman National Parks Board. Furthermore boundaries of the Park become somewhat complicated by the numerous small private holdings along the coast.

Plate 1: The Coastal Sector of Abel Tasman National Park on which the study was centered. View looking north with Bark Bay arrowed. (Photo: Abel Tasman National Park Board)

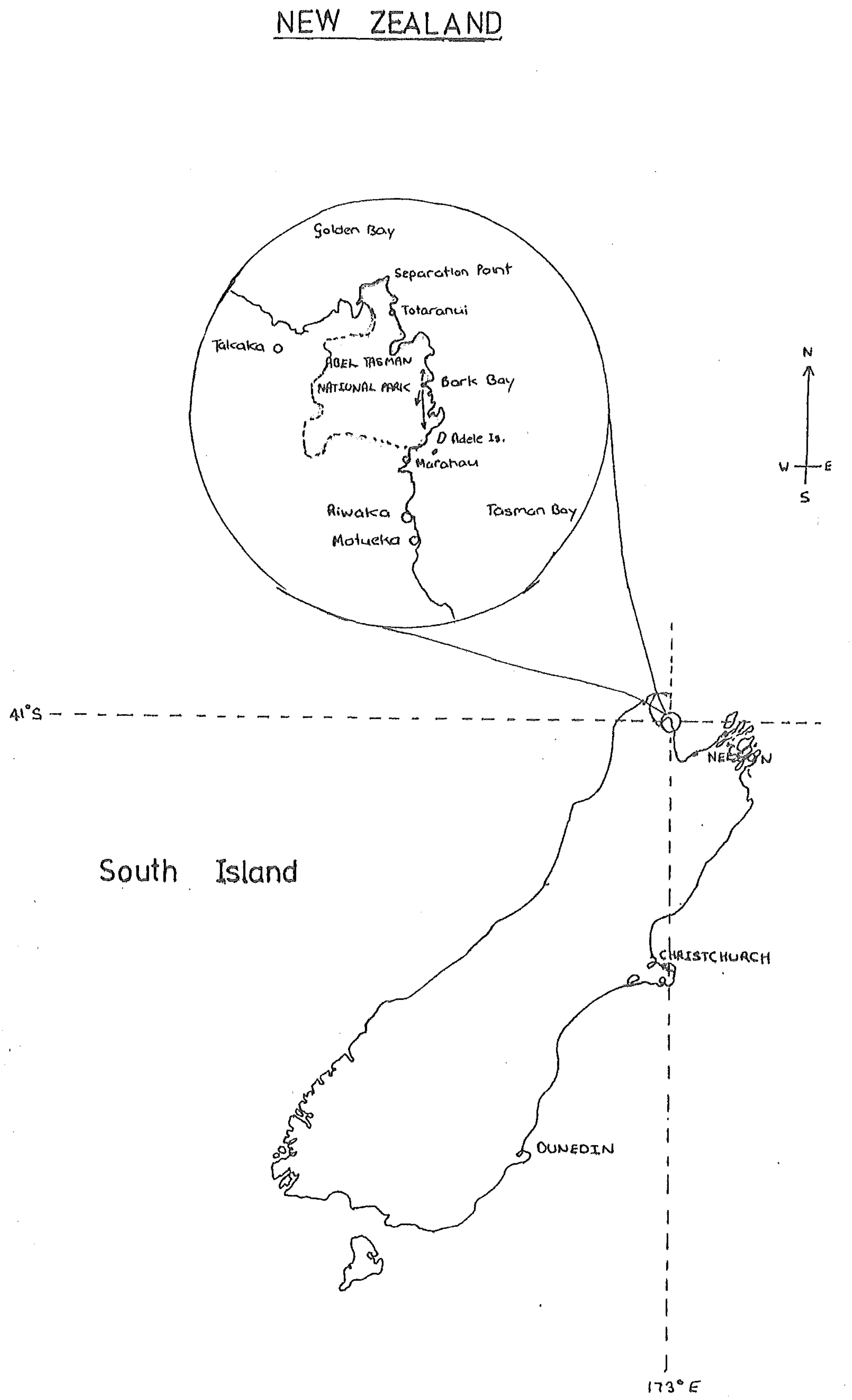
2.2 Environment

1. Physiography

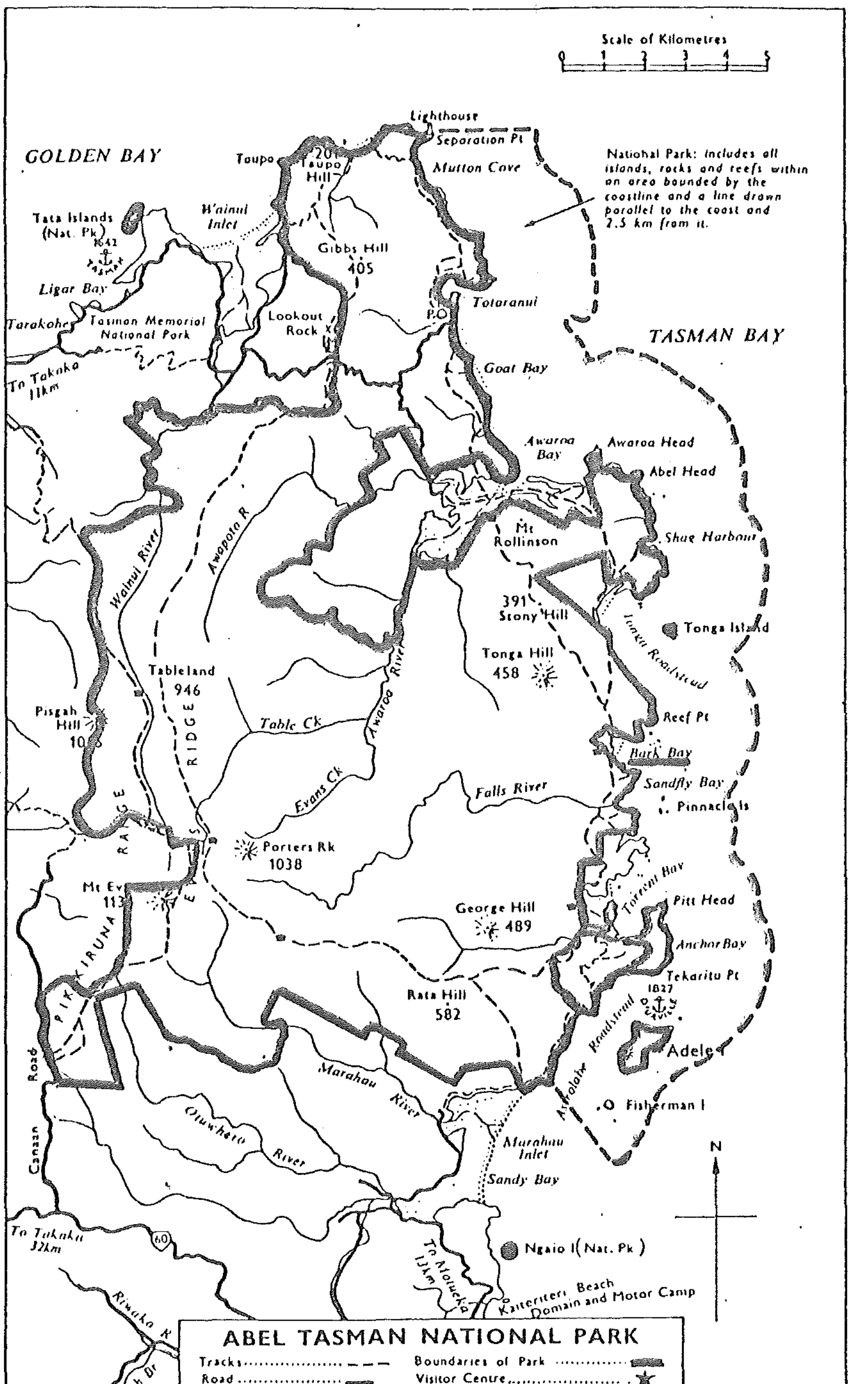
Along the Park coastline much of the land rises steeply for 60 to 90 metres. Thereafter the relief slopes gently up towards Mt. Evans (1134m) and Murrays Peak (1101m) in the Pikiruna Range which, along with Evans Ridge, forms the backbone of the Park. It is the eastern slopes of this granite asymmetrical done that comprise the predominant coastal features of rocky granite headlands separating golden sand beaches. Rarely do hills in this coastal sector exceed 300m although the lie of the land is generally upward sloping. Over a long period the granite mass has been eroded into a system of many deeply entrenched ridges, valleys and bays (Plate 1). The subsequent creation of shaded and exposed aspects has had a profound influence on the vegetation of the Park. (A.T.N.P. 1976). Small creeks and rivers become a feature of the terrain with the overall appearance of the land being a rugged mosaic pattern of deeply dissected valleys and ridges. Recent deposits of alluvium and sand form the only flat land along the coastal fringe.

2. Geology

The whole of A.T.N.P. with few exceptions, is located on a granite mass (Beck, 1964). Grindley (1962) describes it as a massive, white soda granite, resulting from an intrusion during the cretaceous period some 100 million years previous. With time overlying remnant rocks into which the granite was intruded, have gradually been eroded away leaving the granite exposed to weathering. The weathered granite has consequently contributed to the 'golden sand' beaches of the area. With the granite bedrock the drainage in the area is exceptionally fast and this in turn can have a major bearing on vegetation types growing in certain areas, (i.e. without a vegetative cover the soils can dry out very quickly). This feature can also later be importantly related to the present distribution of pine colonisation. The exceptions to the predominant granite geology of the Park are the small alluvial flood plains of the Awaroa and Awapoto River and the scattered deposits of beach gravels and dune sands along the coast (e.g. Totaranui).



Map 1: Location of Abel Tasman National Park



Map 2: Abel Tasman National Park
(Localities & Tenure)

3. Soils

The results of the D.S.I.R. (1968) soil survey show that nearly the whole Park comprises Lowland Yellow-Brown Earths. These soils have generally formed on granite parent materials and are characteristically low in nutrients (D.S.I.R. (1968). The Pokororo steepland soils are acid (pH 5.5) and low in available nutrients, while the Kaiteriteri hill country soils are low in nitrogen. These often skeletal soils being granite based, are very prone to leaching of nutrients and also have low water retention capacities. There appears to be a general shallowing of soils and decreasing fertility from Separation Point southwards (Esler, 1962) and this would tend to indicate that the coastal soils from Bark Bay southwards are probably some of the most infertile and harsh soils within the Park.

It would appear on these soils then, that there exist limitations to growth for most plants, especially indigenous species, and once cleared of original vegetative cover one can forsee lengthy periods in the time taken for the reversion of original forest cover on these sites. Partly due to this, it appears that often better adapted and more competitive exotic species such as Pinus, Hakea and gorse are actively colonising and invading these open areas well before native species attempt recolonisation.

4. Climate

The Tasman Bay region is sheltered from southerly, easterly and the predominant westerly winds by surrounding mountain ranges. Thus the region in general has a sunny, mild climate less windy than most New Zealand coastal areas. Extremes of temperature are not great and there are few severe late frosts. The coastal section of A.T.N.P. to a large extent shares these characteristics (A.T.N.P., 1976) and for the purposes of the survey, climatic data from the Motueka Tobacco Research Station (the closest meterological station to the Park) were used to gain an indication of the general climatic conditions of the area (Appendix 1.2), although major variations between the two sites are quite possible. It should be stressed here, the important role that climate plays in the distribution and dispersal of any plant species. This is especially the case regarding wind and maritime pine distribution and will become more evident in later sections.

a) Winds

Within the Park coastal surface winds are largely controlled by the form of the land. When a westerly air-stream blows on to central New Zealand, the wind in Golden Bay is deflected by the north west Nelson land mass to blow from the north west. The Mt. Evans ridgeline shelters much of the Park from this prevailing wind and instead the deflection of wind by the land prominence seperating Golden Bay from Tasman Bay, has the effect of creating a prevailing northerly or north-easterly wind along much of the coastline, where the study was carried out. Southwesterlies, which find an open way sown the Waimea and Motueka valleys, do also occur from time to time, but are not so prevalent along the coastal margin (A.T.N.P., 1976). Thus at Motueka surface winds are:

calm	53%
northeast	28%
southwest	18%

while at Totaranui further north, the wind pattern has been observed as:

calm	55%	
southeast	18%	
northwest	15%	(A.T.N.P., 1976)

Few strong winds occur and coastal winds are often light and variable in direction. In winter generally more calms occur, while in warmer summer weather, a pattern of late morning and afternoon sea breezes can occur with opposing land breezes at night. The prevailing saline winds can have an important effect on vegetation pattern.

b) Rainfall

As the Park lies open to the north, it receives most rainfall with northerly winds. Coastal areas of the Park receive 1500 to 1650 mm of rain fairly evenly distributed throughout the year, although long dry spells can occur during the summer months (A.T.N.P., 1976).

c) Sunshine

Sunshine hours recorded at Motueka are around 2500 hours annually, although this figure could be somewhat lower in the coastal regions of the Park where sea fog and mist can persist from time to time.

d) Temperatures

Using the Motueka temperatures as an indication gives a mean annual temperature of 12.5°C

Summer average max. = 23°C Min. = 13°C

Winter average max. = 13°C Min. = 1°C

Temperatures seldom exceed 30°C or fall below -3°C. The hill slopes of the Park close to the sea are relatively frost free.

5. Vegetation

The most important feature of the vegetation of the coastal sector of the Park is the abstruse change that it has undergone. It has little resemblance to that which existed when Abel Tasman skirted the coast more than 300 years ago and has undergone even more rapid change in the last 100 years. Originally 90 percent of the land which is now National Park was virgin forest (Esler, 1962), but today evidence of man's impact on the coastal strip in particular, is profound. Although there has been very little forest cleared or damaged above 300 metres, significant areas of coastal vegetation show signs of earlier land clearing operations. Forests which have been regenerating for 10 to 100 years since the last burn or clearing operation, exist side by side with untouched forest.

Exotics such as pines, gorse, hakea and spanish heath all capable of vigorous colonisation, have become a common feature of the coastal landscape as time has progressed, and today we see a ravaged land still recovering from a century of massive modification. Esler in his 1962 study of the Park's vegetation, identified three broad vegetation types as follows:

Beech Forest

The majority of forest found in the Park today contains beech, either in mixed stands (with rimu, matai and miro) or in pure stands containing one of the five beech species (Appendix 8.1) Red beech is the main *Nothofagus* species at all altitudes but gives way to other beech species where conditions favour them. Generally below 600 metres it appears mixed with rimu, matai, miro, kamahi, totara, Halls totara and to a minor extent hinau.

Black beech forest is the natural vegetation of drier spurs and headlands near the sea. *Leptospermum* and *Cyqthodes* spp. are also commonly found within the type which is particularly evident in the southern end of the Park where severe soil limitations eliminate a more diverse flora and result in a relatively simple forest association.

Hard beech trees are numerous within the Park but do not form a well-defined forest. Silver beech along with mountain beech, is generally confined to upland regions. Shrub-hardwood species such as kamahi, mahoe, broadleaf and coprosma's occur within much of this beech forest in varying proportions although pure stands of beech do occur along the coast.

Podocarp/Hardwood Forest

In the coastal valley floors and on broader ridges up to 350 metres a podocarp/hardwood forest type once occupied all the more fertile sites (e.g. Falls River). It is probable that some of this rainforest was cleared, first because of the timber it yielded and also the relatively fertile soil it occupied (A.T.N.P., 1967). The remaining forest is dominated by rata and northern rata with some matai, Halls totara and hinau. Commonly canopy trees are widely spaced and a dense canopy forms at 10 to 12 metres of pigeonwood, mahoe, raurekau, tarata, supplejack, nikau and tree ferns. Closer to the coast rimu disappears to all but the sheltered gullies while the salt tolerant shrubs *Dodonea* *viscosa*, *Oleana paniculata*, and ngaio increase in numbers.

Scrub

Scrub is the dominant feature of the Park's lowland areas. Existing on characteristically dry skeletal granite soils, the existing scrubland areas are of two main types:

1. *Leptospermum* shrublands - on well drained slopes and ridges with characteristic infertile soils
2. Bracken scrublands - on soils of greater depth and correspondingly greater soil moisture.

The main reason for occurrence of these shrublands is a matter of question. Are they 'natural' or were they somehow induced before European settlement of the Coast? This is discussed in Section 5.1 but it is evident that much of the scrub has definitely been induced by unsuccessful attempts at farming.

It is the *Leptospermum* shrubland communities that assumed importance in the study as it is these areas that are being actively invaded by exotics. *Hakea acicularis* is excluding other forms of vegetation on Aweroa Head while *H. sexstylosia* extends from Bark Bay southwards. *Pinus pinaster* and *P. radiata* aided by occasional fires, have replaced native communities over hundreds of hectares south of Awaroa. Gorse and spanish heath have little tendency to establish but are abundant in the induced scrublands.

Although these are the three dominant vegetation types occuring within the Park, they are not necessarily discrete types with mixed stands occuring frequently. As it appeared to be only the *Leptospermum* vegetation areas that the pine was invading, a separate set of vegetation types was devised for purposes of the study (Appendix 1.4).

A notable feature of the vegetation of the Park is the merging of the North Island vegetation with that of the South Island and the large diversity of habitats ranging from sand-dune to sub-alpine bog. Given these occurences one would expect a large number of species present. Esler's (1962) study indicates that the flora is not as floristically rich as would be expected with only 410 indigenous vascular plants being identified. He suggests that the low fertility of the granite soils is almost certainly associated with this and probably accounts for some of the rather surprising gaps in flora (e.g. Kowhai, *Hoheria sexstylosia*, *Melicope simplex*) Esler also noted some 164 exotic species generally occupying man-made habitats such as pastures and damaged forest margins. Relatively undamaged natural communities contained few exotics.

3. HISTORY

It has been necessary to trace historical developments relating to the Park, not merely as a background to the present situation, but more so in attempting to trace, if possible, when, where and why was maritime pine introduced into the region and how did the present vegetation types arise that the pine is invading into? With this knowledge, one may be better prepared to understand the dynamics of this species in terms of its origin within the Park and when it was first planted. This could in itself, verify much of the data collected in the form of ring counts. Even with a great deal of historical research, accurate answers to these questions which I would have welcomed to gain a thorough understanding of the species in the area, have been extremely difficult if not impossible, to find. Even so, it has been possible to draw a broad picture,as to the time and place of origin into the Park,of the species. A brief resume of the history of the coastal portion of the Park also proves useful in developing a later theme on the origins of many of the supposedly induced shrublands along the coast (Section 5.1).

3.1 Maori Occupation

It appears that the geographical features of the Park's coastline provided shelter and food for New Zealand's earliest Polynesian tribes and population was quite significant by 1300 A.D. (A.T.N.P., 1976). Research and laboratory dating of midden bones have confirmed the existence of moa hunting along much of the coast and the scattered occurrence of artifacts gives evidence of a nomadic, wandering existence based on a simple hunting and fishing economy. The first known tribe to live in Tasman Bay were the Ngaitara who were supposed to have died out by 1600 A.D. (Peart, 1937). Successive tribes of Ngati Tumatakokiri and Ngati Apa inhabited the coast until the infamous raids of Te Rauparaha in 1828 when the local tribes were almost completely destroyed. With these raids much of the traditional history of the coast was lost and the new occupiers, Ngati Tama and Ngati Rarua chose to settle on the borders of the present day Park area, leaving the remaining coastline virtually deserted. (A.T.N.P. 1976).

3.2 European Discovery

The European history of the Park area begins with the first visit by Abel Tasman upon his discovery of New Zealand in 1642. The next visit was some 130 years later when Captain Cook made reference to the coastline when circumnavigating New Zealand in 1770. But it was not until the visit of J.S. Dumont D'Urville in 1827 that we gained our first detailed impression of the land and the vegetation of the area. D'Urville anchored in an area now named after his ship, 'Astrolabe Roadstead' and being a capable botanist and entomologist, along with a staff of scientists and surveyors, he made a most accurate survey of the locality and vegetation in the six days he remained in the vicinity (Wright, 1950).

Plate 2: Bark Bay - with Dense Spread of Maritime Pine Evident in Foreground.

3.3 European Settlement

It was not until the 1850s that the coastal region of the Park attracted any settlement, when between 1854 and 1857 some 26 pioneer families purchased land in the area (A.T.N.P., 1976). By 1865 the process of clearing land to establish farms and homesteads was well under way and one gained the impression of a growing and prosperous community striving to make a living from their land acquisitions.

With the general impression that Bark Bay was the initial source of pinaster within the Park, the history of this and adjacent areas, assumes significant importance in the light of this study, as to defining where and when the first trees were planted and the origins of some of the induced shrublands into which the pine is invading.

Bark Bay was supposedly named such prior to any settlement due to the stands of rimu and beech from which bark could be taken for the tanning industry. Consequently the 'Bay traders' would frequently call there and collect bark for sale in Nelson. The first recorded settlement by Europeans at Bark Bay was that of Huffams in 1870 (Host, 1976). Timothy Huffam along with his four sons, Timotheus, Frederick, Richard and Gerard the youngest, arrived in Nelson from Surrey in 1868. It appears from Host's (1976) research, that Timothy tried for many jobs in the brewing industry and in June 1869 after a conversation with a Captain Gilbertson of "Australian Maid" sent his sons to investigate a certain Bark Bay some 40 kilometres north of Nelson. His sons immediately built a pre-fabricated hut and when old Timothy decided to join them, they set about building a homestead. Lands and Survey records in Nelson show that in 1870 Timothy Huffam applied to lease an area of some 51 hectares at Bark Bay, titled Section 27. In January, 1872, the lease was finally issued and a house erected on the identical site occupied by the present Bark Bay Hut. An 1880 photograph of the homestead (Plate 3) shows a well kept property surrounded by a pallisade. Considering that much of the forest at Bark Bay came down to the sea in the early nineteenth century and contrasting this photograph with a similar 1978 view (Plate 5), it was obvious that Huffams

Plate 3: The Huffam Homestead - Bark Bay, 1880.
(Photo: Abel Tasman National Park Board)

had carried out a significant amount of land clearing at Bark Bay.

While living at Bark Bay old Timothy Huffam kept a series of journals (M.S., 1878 - a copy of which Mrs. E.O. Host of Nelson holds). These journals serve to give some insight of occurrences at Bark Bay up until the turn of the century. It appears that while living at Bark Bay, the Huffams were a very industrious family, utilising the land to its utmost. They built up a small bark trade from the native beech and along with building small boats, they cut and sold firewood and fencing posts from the surrounding bush. They also sold fish in Motueka and introduced goats for milk and meat. Such livestock and land clearing operations could then have had an important effect on the original vegetation of the Bay and the surrounding hills.

After leasing the land for 20 years, Gerard was the only son still living at the Bay, with his father. He finally purchased the land from the Crown in 1890 and became the sole occupier when Timothy died in 1893. While at Bark Bay the Huffams had established an orchard with, among other things, apples, cherries and grapes, but there is no reference at all in Huffam's journals, to any plantings of exotic pines. It has been ascertained (Host, pers. comm.)that the Huffams were such an industrious family that any pines planted would more than likely have been planted for a definite use. The Huffams then, may have been aware of the suitability of P. pinaster to a maritime climate. It is quite possible then that they may have chosen the species due to its growth potential and planted it sometime during the period that they lived at the Bay (circa. 1870 - 1904). Indeed, in later correspondence Mrs. Perrine Moncrieff (Nelson) believed that Huffams did actually plant the maritime pine at the Bay but at what date was difficult to ascertain. She also noted that the Huffams planted poplars and hydrangeas at about the same time that the pines were planted, but the pines were the only trees to survive to this day.

The 1880 photograph of the Homestead (Plate 3) shows a reasonably open scrub vegetation behind the house, as does an 1898 photograph of Bark Bay (Plate 4) show a relatively open shrubland vegetation but no evidence of pines. Contrast these with 1978 photographs (Plates 4 and 5) and a dramatically altered landscape is evident, consisting of a Leptospermum shrubland vegetation through which maritime pine are growing. Thus the spread of pines could have commenced from the first settlement of the Bay, but the presence of grazing stock may have tended to restrict pine growing on open ground and confined it to protected situations and more open sites within the indigenous cover. Presumably then, when the Huffams left the Bay, along with their stock, any existing pine regeneration would have a far greater chance of survival.

It does appear likely from my historical research, that the Huffams if anyone, were the early settlers most likely to plant pinaster in the Bark Bay vicinity. Indeed, there still stand three large Cedars (Cryptomeria japonica) planted by Huffams (Bascands, 1976) at the Bay. Presumably the pines were planted before the turn of the century when it appears that

Plate 4: Bark Bay - circa 1898. This early print by Henry Brusewitz shows a characteristically more open shrubland vegetation than exists today. (c.f. the same headland and foreshore on Plate 2).

(Photo: Nelson Provincial Museum)

the Huffams were most active in developing the area. This theory seems the most likely conjecture (Moncrieff, pers. comm.) but in fact there were other people to live at the Bay although it seems rather unlikely that they brought any exotic pines with them.

A Messrs. Cranley and Mould purchased the Bark Bay property from Gerard Huffam in 1904 although their tenure seemed rather shortlived, as not long after Wilson's Quarries at Tonga Bay took over the Huffam house,as the quarry managers residence. Around 1912 the Hopkirk Timber Company purchased timber rights at the Bay but this too was relatively shortlived (Gibbs, pers. comm.).

From Huffams through to Hopkirks time, seems to have been the only period of Bark Bay when modification of the original vegetation may have occurred. It appeares likely through subsequent ring counting, that it was sometime during this period that pinaster was first planted. Following this early period of development, it appears that the forest quickly reverted on the more fertile sites but pines may have already been established by this time and therefore ahead of any suppressive plant competition. Mr. F. Holyoake (Motueka) recalls the open nature of the scrublands above Bark Bay while native forest had quickly recolonised the Bark Bay flats. On his visits to the Bay in the 1930s to pick the wild cherries left by the Huffams, he also remembers open scrubland occuring south of Bark Bay until the ridge on the true right of Falls River. This in fact, corresponds with the area that pinaster has invaded and colonised most aggressively since then.

A brief resume of the history of adjacent areas of coastline to Bark Bay is also worthwhile to gain an understanding of the origins and history of some of the shrublands that pinaster is actively invading. Immediately to the south, Frenchmans Bay and Torrent Bay were first settled in 1870. Boatbuilding was carried out at both and settlement of Torrent Bay continued through until the 1920s (A.T.N.P., 1976). Today open stunted shrublands occupy most of the hill crests, but it appears that many of these areas may have existed prior to

European settlement, as there is no evidence of previous forest cover. The recent appearance of P. radiata and Hakea has extensively modified the existing flora.

The Astrolabe Roadstead area is also rather interesting in that many of the shrublands there, were already existing before European settlement. Indeed D'Urville referred to these shrublands as 'sterile gloomy deserts' as early as 1827 (Wright, 1950). A later Section (5.1) discusses the origins and significance of these shrublands in greater detail. It should be noted that extensive areas of these shrublands also exist right up to Awaroa Inlet and appear to be distinct in origin from those induced by the early settlers' felling, burning and farming practices. In addition much of this coastal land has undergone profound change since the arrival of Europeans. Repeated fires have destroyed much of the coastal forest and shrub vegetation and pines, gorse and Hakea have invaded many of these consequent areas. It is obvious then that many of the present shrublands have also been induced by man's cultural activities.

Gradually the small private holdings along the coast were abandoned mainly due to sea transport problems and the inability of the infertile granite soils to meet the settlers' demands. Logging and milling also died, as easily accessible timber was worked out. Slowly the area encompassed by the present Park became deserted and by the early 1920s the occasional bach owners were the sole inhabitants (A.T.N.P., 1976). This resulted in a coastline in a profoundly modified condition compared with 75 years previous. Although in a somewhat modified condition, the area still warranted National Park status and in 1942 Abel Tasman National Park became officially gazetted. The vegetation and land was then ensured of protection in perpetuity and so initiated the long path to reversion of the natural landscape. Some privately owned sections of land still remain along the coast, but these are in the main small and relatively inaccessible for any form of development.

4. MARITIME PINE SURVEY

This section aimed to incorporate historical findings with an actual field survey of maritime pine, and associated aspects in the Abel Tasman National Park. It was hoped that by relating these historical findings to the previous and present existing pattern of pine distribution and vegetation types, that it would be possible to develop a deeper understanding of:

i) why the pine was there

ii) where is it going? (i.e. the possible danger to the Park).

Survey Procedure

Historical research had established that Bark Bay appeared to be the first area of the Park to have maritime pine growing in it. For this reason the survey was based primarily from Bark Bay. The aim of the field survey then, was to:

i) assess the vegetation associations present and the types that the pine was actively invading into.

ii) assess the distribution of maritime pine in A.T.N.P.

iii) to sample pines for age and thus assess the rate of spread of the pine.

In addition many non-quantitative observations were made with the aim of gaining a deeper understanding of the pine problem in Abel Tasman National Park.

4.1 Field Reconnaissance Survey

To substantiate what was evident from aerial photos and historical research a brief recce survey was made of the area around Bark Bay. From this a hypothesis was postulated that, "the initial maritime pine seed source appeared to be the large pines on the flat* at Bark Bay

* Hereafter called "homestead flat" after the location of Huffam's house.

(Plate 5) and that they appeared to spread outwards from the Bay in a south to south-west direction most strongly, and mainly into low Leptospermum type vegetation".

4.2 Vegetation Associations

From aerial photos three main vegetation types were identified, ignoring the present pine distribution. These were subsequently checked in the field and descriptive notes made on each vegetation type (Appendix 1.4). Areas of each type are shown on map 4. The vegetation types so delineated were:-

1. *Leptospermum* Type 1 (L1) - low shrubland type
2. *Leptospermum* Type 2 (L2) - taller kanuka type
3. Podocarp/Hardwood/Beech type (P/B)

These are all discussed in greater detail in Appendix 1.4. In addition the incidence of pine in each type was recorded, if it were present, and from these and subsequent observations, it was hoped to gain a broad indication of which vegetation types pinaster was already established in and what were the types that it was advancing into.

It should be emphasised that this section of the study was merely a brief investigation into vegetation types being actively invaded by pine with no quantitative data to support my observations. The aspect of the actual plant communities being actively invaded by pine is obviously a prime area for more detailed quantitative research. But it was felt that a broad indication of vegetation types being invaded, based on observations, would be worthwhile to gain a deeper understanding of pinaster in the Park and could possibly highlight further aspects for research.

4.3 Distribution of Maritime Pine

Distribution of pine was initially mapped from aerial photos and these mappings were later verified in the field (Map 3). The areas of pine were then delineated into three approximate density classes:

Dense = 101^{+} stems/hectare
Medium = 11 - 100 stems/hectare
Sparse = 1 - 10 stems/hectare

The pine density map was then overlayed upon the vegetation map (Map 4) to help determine the areas being invaded by pine.

4.4 <u>Sampling for Age</u>

For a study of this kind it was evident that tree ages and distance from initial seed source, would provide the basic data necessary to establish the rate of spread away from the seed source. An increment borer was in the main used to assess tree ages. Due to the difficulties of undertaking such a survey singlehanded, sampling sites were selected to demonstrate what was obvious from aerial photos and the recce survey. But as far as possible, areas sampled were to be representative of the surrounding vegetation. The methodology used for the survey is described in detail in appendices 2.2 - 2.5 and briefly involved the following:

a) <u>Transect Location</u>

Determined by locating the oldest area of pinaster in the Bark Bay region and then assessing the succession outwards in a predetermined direction. The direction of each transect was chosen on the basis of demonstrating what initial observations from aerial photos and a recce survey indicated was occurring. The actual location of these transects is plotted on the aerial photo in Appendix 9.1 and also on Plate 5.

From the recce survey it was evident that the largest trees and apparently the oldest from historical evidence, were those growing on the "Homestead Flat'. The assumption was then made that these trees were the initial seed source of pinaster in the Park. Therefore, any transects in sampling for age distribution of the pine would need to begin on these flats. Also observations

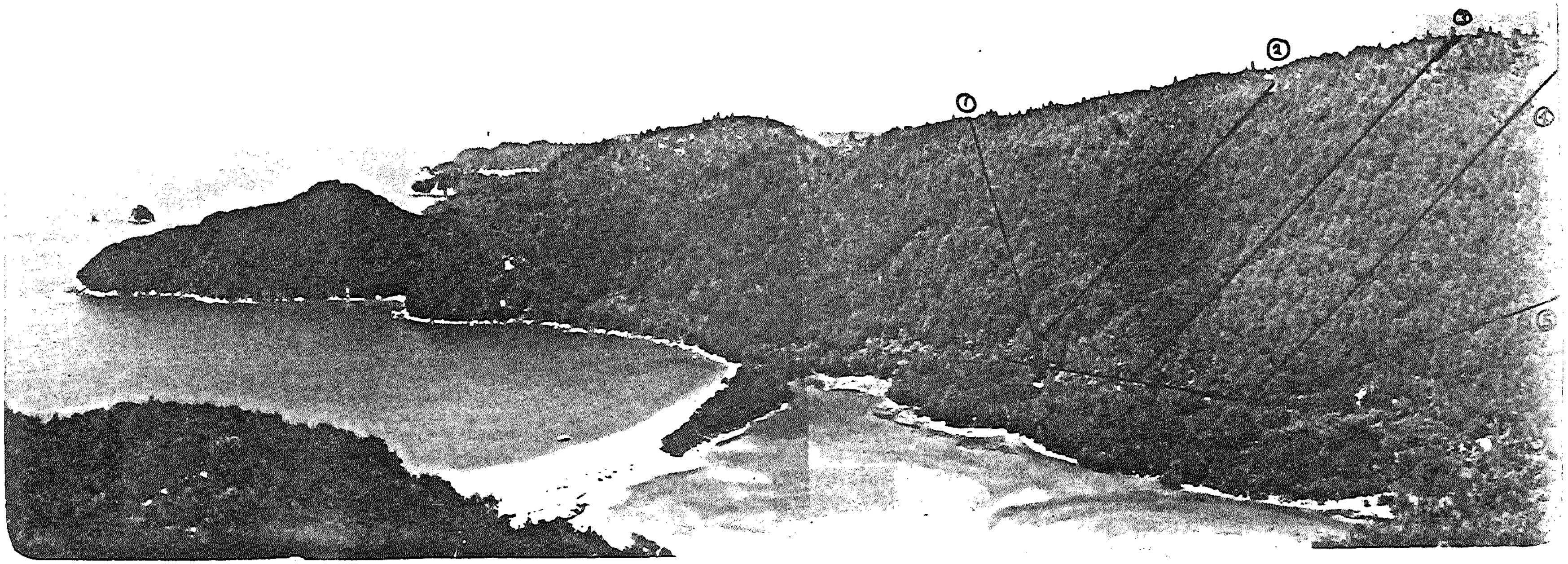


Plate 5: Bark Bay looking south, site of A.T.N.P. hut is arrowed (i.e. former site of Huffam's House). The flat adjacent to the hut is the one referred to as "Homestead Flat" in the text. Note *Pinus pinaster* on hill above flat and *P. pinaster*/*P. radiata* on hill in background. The position of each of the transects (1-5) and the base-line at the bottom of the hill is marked.

indicated that the strongest direction of spread was S.W., S.S.W. from Bark Bay. For this reason transects were located in this approximate direction and so located to follow areas of pine for as long as possible. It was assumed then that these transects would give an indication of the age distribution of pine in the direction of the prevailing winds, (i.e. from the N.E.). The actual detail concerning location of transects is contained in Appendix 2.1.

b) Ageing of Pine

For any survey of this kind the age of the trees is required in order to determine the age class distribution. This was carried out in the main using an increment borer and the techniques used along with the various problems encountered are listed in detail in Appendix 2.4.

It should be realised though, that the ages actually gained in this survey are relative tree ages and not actual tree ages. This was due to the minimum sampling height necessitated by the turning radius of the increment borer handle (i.e. 25cm) and an example is shown in Plate 6. Unless otherwise stated, reference in the script is to these 25 cm sampling height relative ages. Actual tree ages were calculated where necessary using the age/height relationships contained in Appendix 5.1.

c) Ageing of Indigenous Species

In addition to sampling for age in the pine, a number of ring counts were carried out in the *Leptospermum* shrublands and where indigenous species and pine were growing in association at Bark Bay. The principal aim of this excercise was to determine:

i) whether the *Leptospermum* shrublands existed prior to European settlement,

ii) whether the existing vegetation was older than the pine that was growing along with the indigenous flora, OR were the two vegetation types approximately equal in age, proving that the area may have been previously burnt or

Plate 6 : Positioning of Increment Borer on circumference of tree bole. (Note: running line in foreground and thick platey bark).

cleared and the pine recolonised the area along with the indigenous species.

Increment boring was carried out as low on the stems as possible to get a comparative estimate of the indigenous species age, with that of the pine.

d) Survey of Pine Outliers

It was obvious from viewing aerial photos through a stereoscope, that there appeared to be scattered small outlying populations of pine where a number of younger trees surrounded one larger tree. These were termed pine outliers or colonies, with the larger tree termed the founder or parental tree. Each major outlier identified on the aerial photos (Appendix 9.2) was subsequently located in the field to enable various age, height and diameter measurements to be taken (Appendix 2.3). The age of the parental tree gave an indication as to when the seed first arrived in each area and it was hoped to relate this to the timing of any strong winds in the direction of the outlier away from the supposed seed source (i.e. Bark Bay).

It was also attempted to sample every maritime pine north of Bark Bay for age, as it appeared that only a small number of pines relative to the total pinaster population has spread north of the Bay. The few pines on the hill to the true right of Falls River were also sampled to try and determine when the pine first spread to this area. (All this information is recorded in Appendix 9.2.)

e) Age/Height Relationships

In order to estimate actual tree ages rather than relative ages, where required, a number of pines were sectioned at various heights above ground level to determine the change in age with increasing sampling height. This was determined by ring counts and is explained in Appendix 5.1.

4.5 Observations

In addition to the actual survey, a number of observations were made on aspects relating to pinaster in Abel Tasman National Park. There was insufficient time available to quantify many of these, and in so far as they are regarded as personal observations and no more, they do help to illustrate what is occurring. Reference is made to each particular observation, in turn, as they become relevant in the narrative.

5. RELATION OF INDIGENOUS VEGETATION TO PINE DISTRIBUTION

The vegetation types described in Appendix 1.4 are referred to throughout the following sections and are the same as those type previously mentioned in Section 4.2

5.1 Natural or Induced Shrublands?

Many lowland areas of the Park have the characteristic Leptospermum shrubland vegetation described under types L1 and L2, (Map 4). The L1 type is notably prevalent on hill crests along the coast,while the L2 type is generally found on lower more fertile sties. The occurrence of these often extensive areas of tea-tree vegetation is a matter of question, as it is most unusual in New Zealand for shrublands to occur so close to the sea. Is this then a natural vegetation type on these sites or was it somehow induced?

There is evidence to suggest that many of these areas have been here for a long time. Indeed, D'Urville during his 1827 visit to the area made reference to the Leptospermum shrublands betwee Marahau and Torrent Bay:-

> "A few Leptospermum and two or three other shrubs may be seen here and there in these parts. No birds, no insects, no reptiles even" and he likened the areas to "gloomy, sterile deserts".
>
> (Dumont D'Urville, 18 Jan.1827).

Although he speaks of only one section of the coast, it is highly probable that other areas along the coastline were similar. If this was the case in 1827, these areas have undergone very little subsequent chance, save for invasion by pines and other introduced species. Admittedly areas of the present day scrublands have been induced by unsuccessful attempts at farming, but what of those scrublands present in 1827?

It is quite possible that some of the early Polynesian tribes may have fired and burnt the original vegetative cover either accidently or intentionally. These may have never reverted back to their original flora, possibly due to the loss of topsoil and consequent slow recolonisation of the infertile subsoil. On the other hand the community could be a true natural shrubland, its members able to survive conditions of such low fertility that forests were not able to establish. Here it should be stressed that these are hypotheses only. During the field survey a number of ring counts were carried out to determine if these hypotheses could be substantiated at all. By increment boring kanuka and manuka on some of these shrublands, it was hoped to determine whether they existed prior to European settlement. It was also hoped to determine whether at Bark Bay the kanuka was there before the pine. Difficulties were encountered in ageing kanuka, but from kanuka that was aged on the "Homestead Flat" it was established that the pine and kanuka were approximately equal ages (i.e. 70-75 years). This would tend to indicate that the flat was cleared around the turn of the century and both pine and kanuka recolonised the area. On the hills above Bark Bay the picture was dramatically different with large variations between ring counts. For this reason no firm inferences could be drawn as to whether the shrublands were somehow induced, without more detailed research.

There are strong indications though, that the land was once bare of vegetation as no evidence of previously burnt or felled tree stumps was found in these shrublands during the survey. The only indication found that the hill above Bark Bay may have previously been forested was a small isolated pocket of forest, approximating the P/B type, located in a sheltered gully above "Homestead Flat". This pocket was completely surrounded by tea-tree and pine. Cores were taken from a large rimu (86cm DBH) and a red beech (94cm DBH) to determine if there was any charcoal on the growth rings indicating a previous fire. None was found and the only inference that could be drawn from this was that the area may have been burnt long ago in early Maori fires. This remnant sheltered pocket could then be presumed to have been missed in early destruction of the coastal forest by fire. This would tend to support the hypothesis on early Maori burning already established. It could then be postulated that due to the infertility of these soils, that Leptospermum spp. were the only species able to recolonise these sites and when pinaster was introduced it readily invaded into these open shrubland communities, due to its competitive advantage.

The early settlers obviously contributed further to these shrublands with their land clearing operations, which subsequently reverted to open shrublands due to the infertility of the soils. Although no firm conclusions, as to the origins of these shrublands could be drawn, it was obvious that further research would be most worthwhile to understand these strangely vegetated areas.

5.2 Type Specifity of Invasion by Pine

Detailed observations of the area were relied upon to determine what associations were being actively invaded by pinaster and what vegetation types were relatively resistant to invasion. A map plotting distribution and density of pine (Map 3) was overlayed on a vegetation type map (Map 4) to determine types being actively invaded. From these maps it appears that pinaster is indeed type specific with trees or seedlings seldom encountered within the P/B type. Apparently lack of bare sites to colonise and insufficient light prevented the establishment of the pine, and in only three cases was pine found growing within the type. These were all in canopy gaps created by windthrow and the recolonisation of canopy gaps by pine represents the only danger in the P/B type of invasion by pinaster. Should it occur, it would be in relatively confined cases and thus of no significant problem to the Park as once the canopy has closed no further invasion occurs. (Chavasse, pers. comm.)

The main threat of invasion by pinaster appears to be in the Leptospermum vegetation types and most significantly the L1 type. In all cases it appeared to be the L1 type that had the highest proportion of pine regeneration present. The open nature of the type along with high light conditions and bare soil, seems to be readily colonised by pinaster. It was also observed that pine regeneration was highest in the type, where light semi-shade conditions existed, probably serving to protect the seedlings from summer desiccation on the drought prone granite soils.

Plate 7: The Major Vegetation Types at Bark Bay. Note distinct boundaries between adjacent types.

The L2 type had less pine regeneration than L1 principally due to the denser canopy and more shaded conditions. The canopy height and the presence of a frequent shrub-hardwood understory are the only major differences between the L1 and L2 types and the only reason a distinction is made between the two, is that the L1 type appears to be more readily invaded by pinaster.

The distinct boundaries between Leptospermum and P/B types (Plate 7) could possibly indicate early fires or land clearing. One feature that is clearly evident though, is the marked drop-off in pinaster once the P/B type is encountered. A marked absence of pine was also noted in the gullies comprising a hardwood vegetation.

It is evident then that pinaster has colonised the most favourable sites first and these generally appear to be the lower more fertile slopes with the associated L2 vegetation. As distribution of the pine nears the ridge crest above Bark Bay, it appears to be actively invading the L1 type while avoiding the hardwood gullies and the P/B type. Thus pinaster does appear to be type specific in its invasion characteristics, with the L1 type and the more open L2 types being most susceptible to invasion by pine. Other types of gorse and bracken shrublands appear to be relatively resistant to invasion by pine, due to their dense vegetation. Consequently it is the open *Leptospermum* types that most attention should be focussed upon with respect to any pine control operations.

6. DISTRIBUTION OF MARITIME PINE

It was firmly established that the original planting of pinaster was on the "Homestead Flat". The infestation of pine throughout the Park has then been in a consequent radiating pattern from this initial seed source, according to the direction of wind dispersed and availability of suitable sites for colonisation. Thus the distribution of age classes outwards from Bark Bay proceeds generally from oldest to youngest with increasing distance away from the Bay. Consequently the largest pines and densest areas of pinaster are found closest to the Bay as is shown on map 3.

The general dispersal of pine has been determined by prevailing winds and suitable sites for colonisation. The sites most suitable for colonisation have been earlier discussed as those occupied by the L1 vegetation type and bare open ground. On such sites pinaster seems to readily establish itself. Such sites exist all along the coastal margin of the Park, but the prevailing N. and N.E. winds mean that most of thespread of the pine has been southwards rather

Plate 8: Open L1 vegetation being invaded by Maritime Pine. Note radiata pine at Torrent Bay and occasional pine on the Falls River headland.

than north. The strongest direction of spread from Bark Bay appears to be in the S.W., S.S.W. direction,due to the influence of the prevailing coastal winds, but occasionally large trees were encountered long distances from the seed source. Presumably these were a result of strong winds capable of carrying seed long distances.

The consequent distribution of pine is shown on map 3. Briefly the densest area of pine is found on the hill to the south of Bark Bay (Plate 5) with the greatest concentrations of pine being found on the northerly aspect at ridges. This is the region where the rate of spread transect survey was carried out and consequently it is described in more detail in Section 7.3. From the crest of the second ridge clearly evident in Plate 8, the pine has travelled some 1000m to establish itself on the next closest suitable site to Bark Bay. This is on the small headland close to the sea on the true right of Falls River. Although the majority of pine present on this hill was radiata, pinaster was clearly evident although smaller in size due to its relatively recent colonisation of this area.

Pinaster was also present to a small degree, on the headland separating Torrent Bay and Astrolabe Roadstead, a distance of some 4-5km from the original seed source. The coastline south of this was also surveyed and although pinaster was found, there was insufficient time to collect any data on these trees. These few scattered groups of trees are plotted on the map but are really only readily visible from the sea. The southern most pinaster encountered was on a ridge above Apple Tree Bay, this being some 7.2km from Bark Bay.

In the northerly direction, no pinaster was encountered north of Arch Point on the Tonga Roadstead (2.2km north of Bark Bay). Spread in this direction was not as great as it would require dispersal against the prevailing N.E. coastal winds and spread in this direction could only be expected in a strong S. or S.W. wind. Thus it can be surmised that spread of pinaster to date is confined within the Park, to the coastal regions and for a distance of 7.2km to the south of

Bark Bay. Thus the pine presently covers a distance of some 9.2km of the Park's coastline. From these figures and map 3, it is obvious that spread is strongest in the southerly direction.

7. SUMMARY OF DATA

The actual procedure of data analysis is described in Appendix 6.1, but briefly analysis was broken into a number of sections.

7.1 Sampling for Age.

In total, for the five transects established, a total of 68 plots were surveyed from which a total of 199 pines were sampled.

Transect	No. Plots	Total length (m)	Horiz.Dist. (m)	Pines Sampled	Regen.
1	19	900	843	54	8
2	13	600	545	40	4
3	15	700	650	44	-
4	14	650	609	41	-
5	7	300	268	20	3
	68			199	15

Table 1: Summary of Transect Details

A preliminary part of the survey involved confirming the hypothesis that "the oldest pinaster in the Park, and hence the assumed initial seed source, were those growing on "Homestead Flat". From Appendix 1.3 this was deemed correct, and the true age of the oldest tree encountered could be approximated as 72 - 73 years. This would tend to suggest an approximate date of planting of these trees sometime between 1905 and 1910. This data does not strictly correspond with the time that I postulated that the pines were first planted for historical research. That is, that they were most likely planted by the Huffam family while they lived at the Bay sometime between 1870 and prior to 1904,when they left. I also felt that the pines were planted sometime before the turn of the century when from various historical reports, it appears that the Huffams were most active in developing the area.

It could be that the pines actually were planted in the latter days of Huffams duration at the Bay, i.e. 1900-1904. Indeed, if this were the case, my ring counts would tend to support such an event assuming that any difference in actual ages of the trees and the age that I estimated, could be directly attributable to inaccuracies in ring counting.

However, should this not have been the case, there are two further theories that could support my reasoning that the Huffams did in fact, plant the pines earlier than 1900. Firstly, as Mrs. Host ascertains, the Huffams were of such an industrious nature that the pines would have most likely been planted with a definite use in mind. Thus in their own best interests they may have felled and utilised any standing trees for their bark or boat building industry. Here the possibility exists that the pines may have already produced viable seed before being cut down and regeneration could have established, presumably unnoticed from this seeding. Consequently, this regeneration could be the pines presently growing on the "Homestead Flat" that I aged.

The second theory presupposes that goats and sheep introduced by the Huffams (Host, 1976) would have tended to restrict any pine regeneration on open ground. Once stock was retired from the land and farming ceased, (presumably from all accounts, when the Huffams left the bay in 1904) any pine regeneration surviving would stand a greater chance of becoming established. Assuming that the Huffams did in fact, fell the larger pines for their own use before they left the Bay, this could account for the gap in age classes of pine from the oldest tree encountered (70 years), up to the time at which Huffams were most active in the Bay (i.e. prior to 1900) and presumably planted the trees. However, any of these three theories may be correct and all are based on the assumption that Huffams were indeed the first to introduce pinaster to the Bark Bay area which seems the most likely conjecture from my historical research and ring counts.

7.2 Rate of Spread

A summary of the rate of spread for each transect taken from Appendices 6.2 and 6.3 is given in Table 2.

Transect	Bearing °mag	Direction	Rates of Spread (Horiz. distance)	
			Metres/year	years/kilometre
1	170	SSE	11.1	90.4
2	205	SSW	9.2	108.3
3	205	SSW	9.2	108.4
4	205	SSW	7.6	131.0
5	260	SW	9.6	104.6

Table 2: Rate of Spread Summary

From this, there is a range in rate of spread from 7.6m/year to 11.1 m/year depending on transect. A mean horizontal rate of spread for all five transects was calculated as 9.1 m/year or 110.6 years/kilometre. At this rate it would take some 111 years to cover 1 kilometre of land with the density of pine that is presently growing above Bark Bay assuming that country was as readily available for colonisation by pine as the land above Bark Bay had been.

It must be recognised that these estimations are broad approximations only, due to the very subjective and difficult nature of determining rate of spread. Also actual rate of spread is highly dependent on site factors and as the transects had been located where a pattern of spread was apparent, the influence of site factors should be borne in mind. With regard to the strongest direction of spread, it appears that this is in the S.S.E. direction (11.1 m/year). But on this transect there was a significant area located in a gully without pine. For reasons such as this and other site variables, no firm inferences could be drawn as to the strongest direction of spread except that it appeared to be generally strongest in the southerly direction. Strictly speaking, these mean rates of spread are only for the transects located on the hill to the south of Bark Bay. However, they do give a rough indication of what pinaster is capable of given open ground to colonise and assuming the prevailing wind to be from the north.

7.3 Graphical Analysis

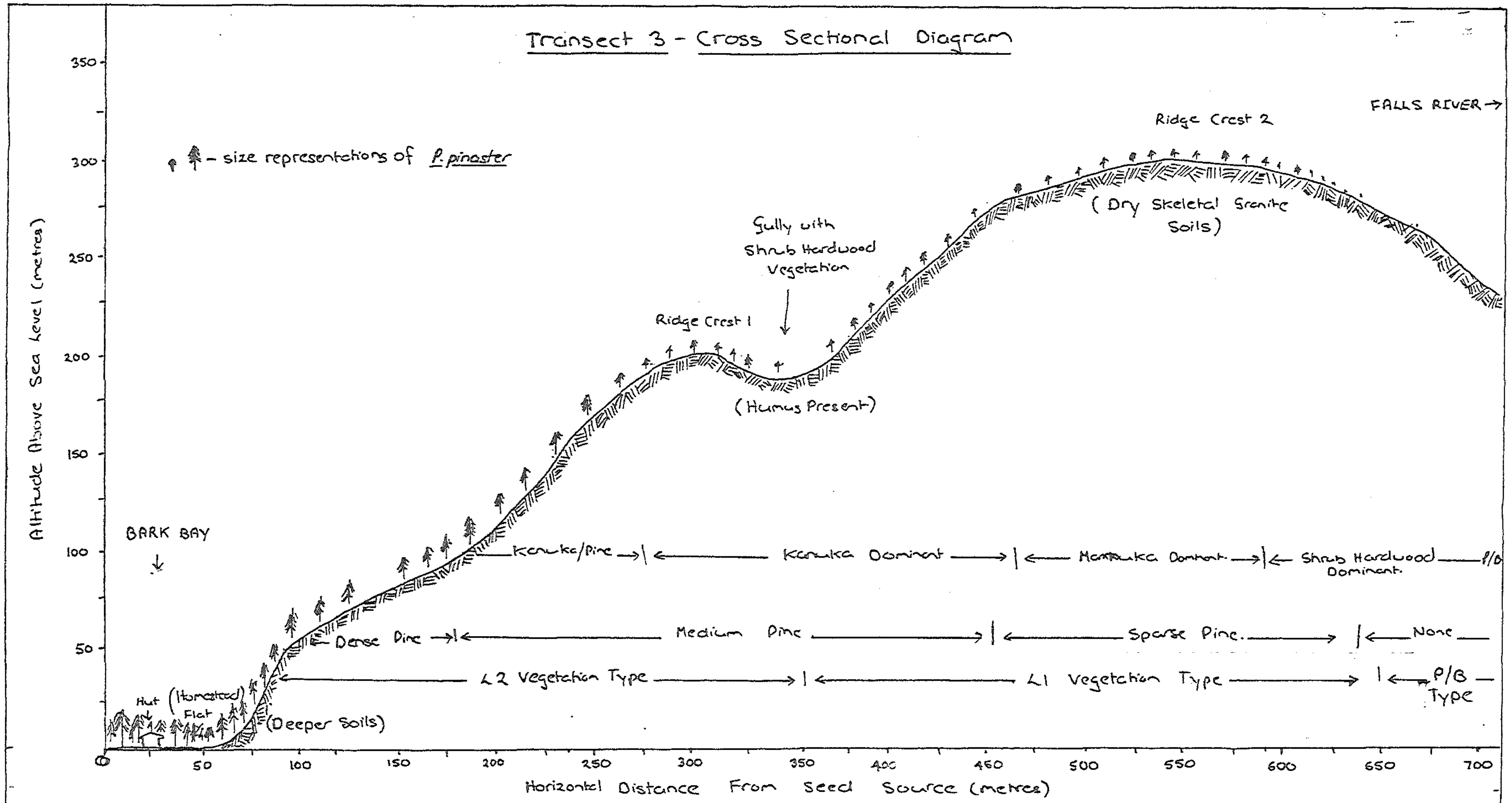
Appendices 7.1 - 7.5 show the relation of horizontal distance on height, age and DBH for each transect. Although most reference is made to age distribution, distributions of height and DBH also show very similar relationships, and help to illustrate the general pattern of spread evident with pinaster. Rates of spread were also plotted. Regression analysis was not applied to any of the graphs due to the stepped nature of spread in certain cases which would mean that the mathematical model would not be truly representative of the biological model. All transects can be traced on the aerial photo in Appendix 9.1 which also delineates gullies and vegetation types that each transect runs through.

1) Transect 1

Transect 1 (Appendix 7.1) shows an initial falling off in DBH, height and age away from the seed source. This is as the transect passes through the L2 vegetation type and then falls off dramatically as the transect passes over the first ridge above Bark Bay (300m) and drops into a P/B gully. On the other side of the gully the mean age resumes at about 30 years which is relatively consistent with the age of the pine on the opposite side of the gully. The major difference in the latter part of the transect is that it passes through a much shorter open L1 vegetation type, and there is a marked reduction in incidence of pine, once the P/B type is encountered. The graph also shows a marked drop off in age classes from 54 to 42 years in the space of 100 metres. This would tend to indicate the stepwise nature of spread by pinaster, whereby there is a gap in age classes equal to the time that new seedlings take to grow up and produce fertile seed and so spread outwards again.

2) Transect 2

This transect (Appendix 7.2) shows a similar relation to the above but of particular interest is the apparently even aged stand covering some 150 metres between



PLOT NO.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
MEAN AGE (years)	–	56	–	52	41	35	32	29	27	28	25	18	7	–	–
MEAN HEIGHT (metres)	–	18	–	17	14	13	12	10	9	8	7	6	2	–	–

Fig. 1: Representative Profile Diagram - Transect 3.

plots 2 and 5. This could have been a result of an initial seeding in this direction.

3) Transect 3

Transect 3 (Appendix 7.3) shows the most general relation occuring in the distribution of pinaster and for this reason has been plotted as a profile diagram generally representative of the spread of pine at Bark Bay (Fig. 1).

4) Transect 4

This transect (Appendix 7.4) begins by passing through some of the densest pinaster found within the Park (Plate 5). Consequently there is a high degree of competition and a large number of pines appear suppressed. This would tend to explain the large initial drop in DBH

Plate 9: Densley Stocked Maritime Pine on Transect 4.

on the graph compared with mean age. In these areas of dense stocking the understorey is relatively sparse containing only mingi-mingi, black ponga and occasional kanuka (Plate 9). In many cases the pine has overtopped competing kanuka and pine resulting in a high proportion of dead stems. Due to the free draining nature of the granite soils, there is a dense carpet of non-decomposing pine needles and consequently no humus layer. The region of closely spaced pine runs out at about 250 metres when there is a transition of pine into the L1 vegetation type. On the main ridge the vegetation consists of emergent pines growing over low manuka shrubland vegetation (Plate 8).

5) Transect 5

Transect 5 was the shortest of the five transects (Appendix 7.5) being only some 270 metres long before it ran abruptly into the P/B vegetation type, where no pines could be found. There was also an abrupt transition between the L2 and L1 vegetation types and a marked consequent increase in pine regeneration in the L1 type.

6) Histogram

With transects 2, 3 and 4 following an identical direction and occuring on very similar terrain, it was decided to construct a histogram of the various parameters. Age, height, DBH and rate of spread were averaged for the three transects (Appendix 6.4) and plotted against cumulative distance classes away from the initial seed source (Fig.2).

The histogram shows the similar pattern of decrease in age, height and DBH with increasing distance from seed source. Also the rate of spread histogram exhibits two peaks corresponding with the crests of the two ridges above Bark Bay, indicating the rate of spread has been fastest approaching these two ridge crests. A mean rate of spread for these three transects was calculated as 8.7 metres/year.

7.4 Discussion

In summary all the graphs show generally similar features. The most prominent feature being that of the absence of pine in the P/B vegetation type. In most circumstances age, height and DBH follow similar relationships,

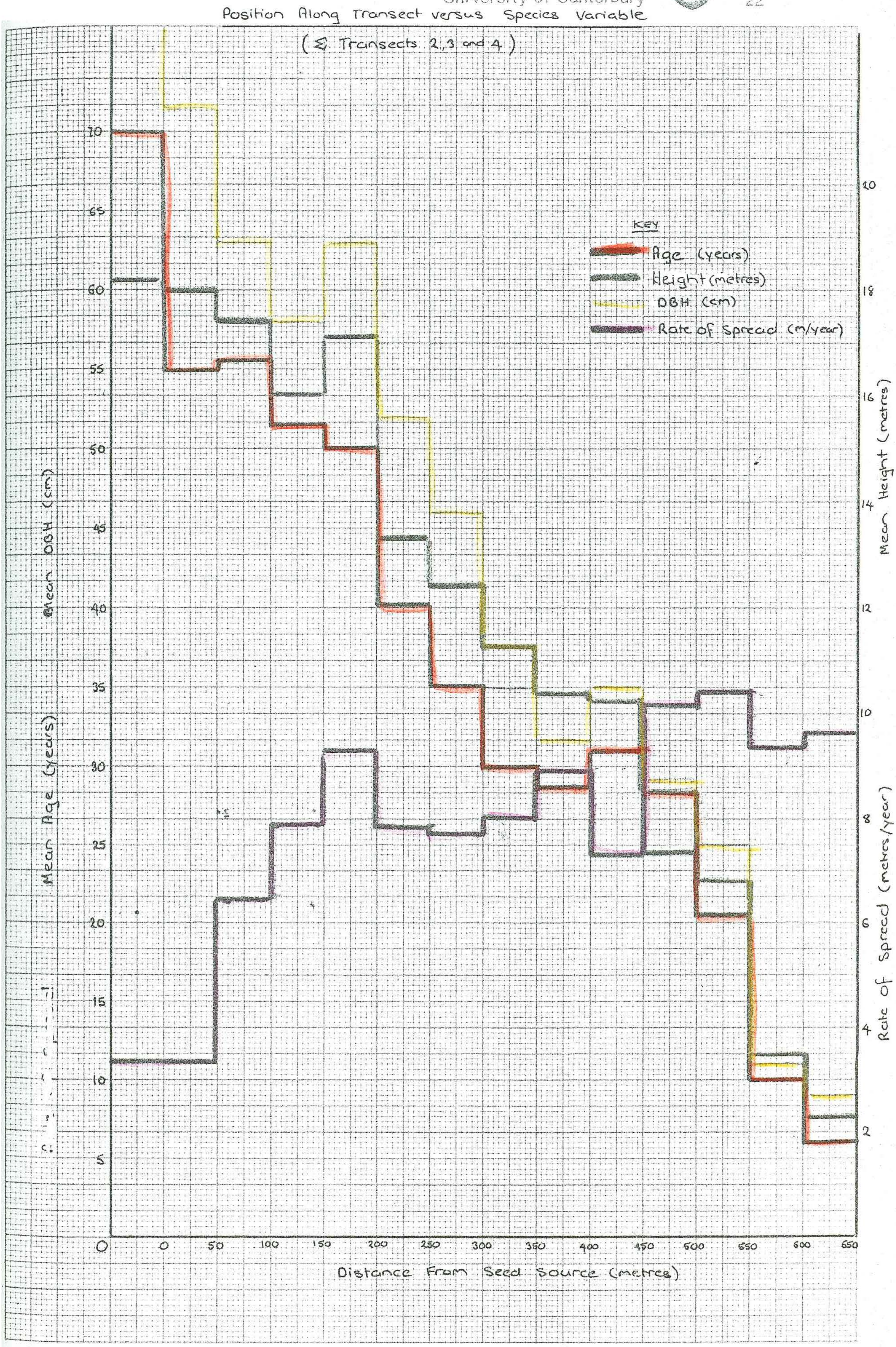


Fig. 2: Histogram - Transects 2, 3 & 4.

while rate of spread on the other hand, was significantly different. The same general pattern of rate of spread was found for all the transects. That is a somewhat faster rate of spread as the pines colonised the foot of the hill close to the "Homestead Flat" and then a slowing in rate near the crest of the first ridge above the Flat. Then in all cases except transect 5, there was a dramatic increase in rate of spread approaching the crest of the main ridge behind Bark Bay. This demonstrates that the pines are presently actively invading these low, open Leptospermum shrubland areas and this was further illustrated by the large amounts of pinaster regeneration encountered in the L1 vegetation type.

Generally the density of pine in stems/hectare was highest closest to the Flat and the pines growing near ridge crests were found to be more stunted in height although many had large boles. This could be a result of the exposed conditions near the ridge tops and the influence of prevailing saline winds.

8. ECOLOGY OF MARITIME PINE

Maritime pine is native to the mountains of Spain and North Africa where it grows from sea-level to above 750 metres in altitude and through a wide climatic range (Sweet & Thulin, 1962). Indications are that it was probable the first exotic conifer successfully introduced into New Zealand (Weston, 1957). Indeed, it was sufficiently well established in Northland in 1840 for a local enthusiast to have considered it indigenous and seeds were sent to Europe as those of a new pine named P. nova-zelandica (Adams, 1915). Weston (1957) records that it was being planted at Lyttelton and Christchurch as early as 1863 and Auckland in 1866. From this it appears quite possible that Huffams indeed may have introduced pinaster to the Bark Bay area between 1870 and 1904 as it seems that stock was well established in New Zealand by this time.

Two major provenances exist of the pine. The Atlantic coastal type is characterised by fast growth and generally good form while the Mediterranean group has slower growth rates and is characterised by dense, dome-shaped crowns (Sweet & Thulin, 1962). It was obviously impossible to determine which provenance was growing within the Park but most of the older trees did exhibit dense rounded crowns. FRI (1976) states that most pinaster in New Zealand is generally of poor form apart from some of the heavily branched, vigorous open-grown pine. The pine as such exhibits both adult and juvenile growth forms (Plate 13).

Essentially the pine is a low level maritime species that thrives in a congenial oceanic climate (Dallimore and Jackson, 1966). Scott (1962) notes that as such it is a light demanding pioneer species and this probably explains the reluctance of regeneration to invade into the P/B vegetation type and other areas with closed canopies. On the other hand, it was seen to readily colonise open shrubland communities such as the L1 and more open L2 vegetation types.

8.1 Features of Habitat

The coastal climate of the Abel Tasman National Park would seem to suit *P. pinaster* as it is quite tolerant of salt winds, while being adversely effected by frosts. (Scott, 1962). From earlier climatic data it is evident that the coastal region of the Park is relatively frost free and this would tend to favour the species here. Also Scott states that the tree thrives in winter rainfall, but not in zones with summer rain. Again this is closely akin to the climatic conditions of the Park.

Perry (1939) reports that pinaster thrives on light and well drained soils and can tolerate considerable summer drought and dry soil conditions caused by such drought. It is especially adapted to such conditions because of its ability to develop a deep tap root in these soils. It also has an ability to tolerate very poor infertile soils, especially sand, and those low in nutrients (Scott, 1962). Here it can be seen that many of these features are consistent with the sites that pinaster is already occupying within Abel Tasman National Park. The predominant granite soils of the shrubland areas of the Park are obviously very well drained and consequently drought prone in summer. Many of the low shrublands also contain characteristically infertile soils. Clearly many indigenous species would find it very hard to colonise such sites, once cleared of previous vegetative cover, thus there is relatively little impeding the invasion of pines onto these sites. Given the clear competitive advantage that they have over the indigenous flora it is easy to see why the pines are readily colonising these sites at the present rate they are.

8.2 Seeding

In the literature nothing could be found regarding the self pollination of pinaster or what contributed to good seedfall years if such years occurred , periodicity of seed-fall, or even what time of year seed-fall occurs in the southern hemisphere. If it could be deduced that seed only fell at certain times of the year, this could have an important implication for understanding the invasion pattern by the pine. That is, that it would only be those strong winds occuring over the period at seedfall that could lead to long range spread of pine seed. Knowing the directions of such winds it could possibly be predicted, what new areas may have been colonised as the result of wind dispersed seed. Such areas would then be watched accordingly. These aspects could all help to further understand invasion characteristics of P. pinaster. Weston (1957) did note that with P. pinaster good seed crops are the usual case. Furthermore, Allsop (1951) found that first production of fertile seed by pinaster usually occurred after 10-12 years, in New Zealand, but casual seedings as early as five years of age have been observed. Indeed during this study cones were often noted on trees in the 10-12 year old age class and even a seven year old pine was found bearing cones. None of these cones were tested for viable seed though, so it would be difficult to draw any firm conclusions from these few observations. The inference here though, is that once a pine has become established on a new site, there is usually a period of 10-12 years before it can act as a potential seed source, thus increasing the invasion of pine onto new sites. Therefore, if further invasion is to be checked, such pines found present in areas of the Park where they are not wanted, should be destroyed well before they reach age 10 (this is usually about 2-5m height).

Closely related to dispersal of seed within the Park is the finding by Sweet and Thulin (1962) that trees further towards the centre of a stand of pinaster carry significantly more cones than those on the outside of a stand. This is presumably due to a gradient in pollen concentration within the stand. This incidence of cone setting would tend to indicate that a large proportion of fertile seed leading to the invasion by pine is in fact arising from the middle of denser pine stands, rather than the peripheries. Thus, given time colonies expanding in size could contribute quite significant amounts of seed for regeneration on surrounding suitable sites, unless they are controlled or eradicated.

8.3 Regeneration

It appears that pinaster seed germinates well but initial growth is relatively slow (Hopkins, 1971b). Hopkins (1971a) also found that seedlings even though slow growing, are relatively drought resistant and do not run the usual risk of desiccation usually associated with many of the other Pinus species seedlings. Here is evident another competitive advantage of pinaster in colonising many of these somewhat harsh open shrubland sites in Abel Tasman National Park. Natural regeneration seems to occur freely where suitable sites exist and is most favoured on open sites with well drained soils (Scott, 1962). This was found to be the case throughout much of the study area.

Induced regeneration is a problem associated with P. pinaster that regularly follows fires and man's land modifying activities (Weston, 1957). Chavasse (1978) in a Forest Research Institute study presently underway into invasion of pine in New Zealand, found that the major cause of invasion by pinaster was former burning or grazing of land. Indeed, Fenton (1951) notes the abundant and vigorous P. pinaster regeneration following the 1946 Taupo fires. Pinaster appears to regenerate freely following fire as being a semi-closed pine it can retain closed cones for a long time (Scott, 1962). The action of heat from fires can serve to open such cones prematurely and so hasten regeneration. It has been earlier established that many of the shrubland communities of the park have been there for some time, but admittedly other areas of vegetation have been induced by man's activities in the area (e.g. Tinline Stream). On such areas on induced colonisation by pine has most probably occurred as pines with their competitive advantage over indigenous species, readily colonise into these areas cleared of natural vegetation by sporadic burning or land clearing operations. With the designation of National Park status these areas are now protected in perpetuity from land modifying activities insofar as is possible. It is important then, that fire prevention and control in these coastal areas, is a major priority as any fire in these indigenous vegetated areas could have, as a consequence an accelerated rate of invasion by pine. Thus although natural regeneration of pine may be occuring all the time, induced regeneration by pine can be kept to an absolute minimum with effective fire prevention and control.

8.4 Pathology

Generally *P. pinaster* is a healthy species in the maritime climate although Weston (1957) records that damage by the defoliator *Selidosema sauvis* is possible. Also it is susceptible to attack by the root rot *Armillaria mellea* in New Zealand. The pine observed during the study was in a predominantly healthy condition and the only evidence of disease were occasional trees affected by sooty moult (*Trichopetheca asiatica*) in areas of close proximity to manuka stands infested with Manuka Blight (*Eriococcus orariensis*).

8.5 Natural Features

1. Reaction to Wind

According to Weston (1957) *P. pinaster* trees in unthinned stands are often easily broken off by wind. F.R.I. (1976) found that generally the pine produces less late wood in New Zealand than similar provenances overseas. As a consequence the stems may be less wind resistant due to the loss of strength caused by a reduction in late wood. Here problems of canopy gaps within the existing cover of pine in the Park may occur with consequent recolonisation by pine as noted earlier.

2. Fire

An important feature to recognise with maritime pine is the high fire danger associated with it. Being a resinous pine, the sapwood is capable of producing copious amounts of resin and in areas with exceptionally dry summers, the presence of this resin represents a very real fire danger (Scott, 1962). Indeed, Abel Tasman National Park does have very dry summers from time to time and thus fire prevention in these inflammable stands of maritime pine, is of utmost importance both to stop destruction of other vegetation within the Park and to prevent inducement of pine regeneration following fire.

From this brief review of the literature, it can be seen that in the context of pinaster's presence in Abel Tasman National Park it does have many features which serve to make it an aggressive coloniser given suitable sites.

9. DISPERSAL MECHANISMS

Wind dispersal is the major mechanism of seed dispersal employed by all species in the Pinaceae family (Dallimore & Jackson, 1966), and it seems most likely that wind dispersal of seed is primarily responsible for the radiating pattern of pinasters distribution outwards from Bark Bay, upon sites suitable for colonisation by pines. It also appeared evident from my observations that there are two mechanisms of wind dispersal responsible for the present pattern of pinasters distribution. One is a rather slow mechanism of spread via prevailing winds, while the other is the rapid mechanism of spread of seed via strong gusts of wind.

9.1 Stepped Dispersal

This is slow step by step migration of regeneration away from the seed source in the general direction of the prevailing wind, and is readily visible on the hillslopes to the south of Bark Bay. The stepped nature of spread is also evident along some of the transects, (transect 2, Appendix 7.2) where age decreases in small steps with increasing distance away from the seed source. Seedlings grow up adjacent to seed trees and these grow up and seed out. The consequent gap in age classes is approximately equal to the time pinaster first takes to produce viable seed. From the graphs in Appendix 7.2 - 7.5 this appears to be from 7 to 15 years. Similarly Allsop (1951) gives the time for first production of fertile seed by pinaster as 10 - 12 years, with casual seeding as early as 5 years having been noted.

9.2 Rapid Long Distance Dispersal of Seed

In addition to stepped dispersal, there is evidence of spread occasioned by strong winds capable of carrying the pinaster seed considerable distances. Such pines are usually found growing long distances from the seed source in the area. Pinaceae seeds are generally fairly heavy compared with many other seeds, but the large lobed wings on pinaster seed make it quite capable of travelling quite long distances in strong winds (Dallimore, 1966). Such winds must usually be greater than force 6 on the Beaufort Wind scale (i.e. greater than 22 knots) (Oliver, 1974). Bearing this in mind, it was hoped to relate the occurrence, strength and direction of winds of force 6 and above, to the present distribution of pinaster. From this it was hoped that some correlation could be obtained between dates of these major winds in the Nelson region and age classes of pinaster in different areas of the Park. The Meterological Service at Nelson airport and the D.S.I.R. Research stations at Riwaka and Motueka, were contacted regarding such data. Nelson airport returned the most useful data with Meterological regords going back to 1940. It should be emphasised though that such an extrapolation of climatic records has many failings but in conditions with very strong pressure gradients, especially when the wind approaches over Tasman Bay, high winds at Nelson are probably also present at Abel Tasman National Park (Tomlinson, pers. comm.). From these records two occurrences stood out above all others:

22 February, 1944	Max. gust	= Ø60/82 knots
12 March, 1975 (Cyclone Alison)	" "	=120/75 knots

From my sampling for age, the oldest tree encountered outside the immediate Bark Bay vicinity was only 48 years old. Thus it could be assumed that prior to 1930 pinaster was confined to the Bark Bay environs and it was not until 1930 that rapid long distance spread by wind, resulted in the establishment of the first pinaster away from the Bark Bay area. Prior to this, stepped dispersal had been the major mechanism of spread of pinaster. South of Bark Bay the first evidence of long range dispersal of pinaster was found on the headland at the true right of Falls River (Plate 8). On this hill the largest pinaster (i.e. over 1.5m height) were sampled for age to try and determine when the pine arrived at this site. Smaller pine less than 1.5m height was disregarded due to the possibility of its seed originating from pinaster alredy established on the headland. Of the 20 largest pines sampled on the hill, the oldest was found to be 30 years proving that the seed had first arrived here sometime around 1948. In addition a total of 8 trees varying in age from 27 to 29 years, were encountered proving that there must have been strong winds in this general direction at that time, capable of transporting seed from the Bark Bay area. A number of Maritime Pine were also established on the barren scrubland headland separating Torrent Bay and Astrolabe Roadstead. This was a distance of some 4 - 5 km from Bark Bay, but through lack of time, I was unable to sample any of these pine. Fortunately Chief Ranger Rennison carried out a pine eradication programme over a major part of this area in March 1978. Consequently data for these pine were collected during these operations. Although the major pine in the area was radiata (409 of the total cut) a total of 22 pinaster were also destroyed. Interestingly, he found two pinaster aged 27 years and the oldest aged 30 years. This tallies significantly with the oldest pine found at Falls River and established that the seed first arrived around 1948. The inference that can be drawn here is,that it is most probable that the same strong winds from the north that blew seed onto the Falls River headland, also carried the seed further south to Torrent Bay. Accounting for the sampling height and the possibility that the wind blown seed may have lain dormant for several years, it is highly likely that this seed could have been dispersed long distances in the major winds of 22 February, 1944. Furthermore, there are also occasional instances of pinaster occuring along the Astrolabe Roadstead as far south as Apple Tree Bay some 7.2km from Bark Bay. Time prevented sampling of these but they appeared to be of similar size to those seen at Falls River and Torrent Bay and it would be most interesting through increment boring, to see if these too were of similar age structure and therefore possibly originating from seed dispersed in the same high winds of 1944.

Another factor of dispersal apparently resulting from these high winds is that of pine outliers. From the aerial photos (Appendix 9.2) it was evident that there were a number of groups of younger age class trees clustered densely around a single larger tree. These I termed "Pine Outliers", where one parental founder tree presumably resulting from a wind dispersed seed, had established itself, grown up, and produced viable seed after some time, which once dropped, often germinated and established itself close to the parental tree. With time, many trees grew up around the single oldest tree. A total of ten outliers were identified from aerial photographs (Appendix 9.2). These were subsequently checked in the field by recording ages, DBH and heights of the parental tree and the next ten largest trees (Increment Core Data Sheet II, Appendix 3.2). From these results it was aimed to determine the age of the

Plate 10: Typical Maritime Pine OUtlier (Outlier No.7)

outlier founder tree and by sampling the next ten largest trees, it was hoped to determine the gap between the founder tree growing up and producing its first viable seed, as well as making sure that there was only one founder tree in each outlier. The following is a summary of the results:

Outlier	1	2	3	4	5	6	7	8	9	10
Oldest Tree Age	46	45	50	56	36	46	45	32	47	48
Next Oldest Tree Age	27	29	34	37	21	28	23	18	28	36
Age to Produce viable seed	19	26	16	19	15	18	22	14	19	12

Table 3: Pine Outliers - Age Data

It becomes apparent from this data that what had been observed from aerial photos was in fact, the case. In each case a single founder tree acts as an individual seed source and was responsible for initiating of younger trees in an outwards radiating pattern. Outliers 1 - 6 were located on hill country south of Bark Bay while outliers 7 - 10 were found in the Long Valley creek catchment just north of Bark Bay. All the outliers were found to be growing in the L1 vegetation type. The age of founder trees vary in age from 32 to 56 and presumably are a result of strong

Plate 11: Outlier with Parental Founder Tree surrounded by Progeny (Outlier No.2)

winds in the direction of the outlier around the time period 1978 minus the oldest tree age. The time taken for each of the ten founder trees to produce their first offspring varies from a period of 12 years to 26 years, the average time taken for the ten trees being 18 years. This period is not quite in line with the earlier stated period pinaster takes to produce viable seed, but here the seed may be lying dormant on the ground for several years before it germinates and establishes itself. In addition to the outliers noted, it should be realised that many smaller outliers presently growin in size may have been missed as until they have expanded significantly they are not readily discernible from aerial photos.

In all the outliers observed the founder tree was significantly larger than the progeny. Generally there was a circular radiating pattern of older and larger trees closest to the founder tree with successively younger age classes further out (Plate 11). Also pines growing within an outlier generally had smaller DBH's and heights than equal age open grown pine. This was a result of suppression of trees within the outlier due to intense competition for growing space. Often dead and dying pines which had been overtopped or crowded out were observed within the outliers. This was most evident in the densest outliers (3, 9 and 10) but the less dense outliers (1, 2) also showed similar features. In most cases there was no regeneration of any kind inside the centre of the outlier and instead there was usually a thick carpet (5 - 10cm) of pine needles. However, on the peripheries of the outliers where there was less competition and more light, pine regeration was often abundant indicating that the outliers were actively expanding in size presumably aided by older trees in the stand, capable of producing fertile seed in addition to the founder tree's seed. Bearing all these factors in mind, one may pose the question as to how these outliers originate. It is fairly evident that windblown seed germinates on a suitable site and establishes itself. Consequently a tree grows up, but in sites as isolated from other pinaster, as those at Long Valley, one wonders how the seed is fertilised to become viable. Here the possibility exists that occasionally pinaster inbreeds via self pollination. This implies a very narrow genetic base and could suggest why some trees growing in outliers are inferior and very poor quality trees.

In addition to the four outliers found in the Long Valley Creek area, there were a number of scattered free growing pines amongst the L1 vegetation type predominant there. The majority of these trees were also sampled for age and their respective ages recorded alongside the position of each tree on the Long Valley aerial photo (Appendix 9.2). Two possibilities exist as to the origins of these trees. They either arose from seed blown north from Bark Bay by a southerly wind, or alternatively they may be the progeny of the significantly older founder trees found in each of the four established outliers at Long Valley. It appears from my ring counts of outliers that the first pinaster arrived in this area sometime between 1928 and 1933. There are only three such trees in the area (i.e. Outliers 7, 4, 10), and of the remaining pinaster growing at Long Valley the majority are under 30 years in age. This is a strong indication that rarely does seed blow from Bark Bay, north to here and become established, but rather the majority of pinaster at Long Valley is the progeny of a few trees that have grown from seed which had been originally wind dispersed from the pinaster at Bark Bay. It appears that these trees must have been prolific seeders to account for the present distribution of pine at Long Valley.

The area is also most interesting in that it represents the northern-most limit of pinaster within the Park.

Presumably this has been a result of strong winds from a southerly direction carrying seed northwards. Interestingly though, the pine has not continued as far northward (2.2km), as it has southward (7.2km). The topography of the land and the prevailing wind direction could provide answers to this. The wind pattern is predominantly from the north in the Bark Bay region, and southerlies are comparatively rare and even when a southerly does occur it would have to be of sufficient strength to counter the effects of uphill topography. Directly to the north of Bark Bay lies the long Stony Hill Ridge which the wind must carry the seed up and over before it finds the closest sites north of Bark Bay

Plate 12: Outliers 9 and 10 at Long Valley Creek, the largest outliers encountered and located some 2km north of Bark Bay.

suitable for colonisation by pinaster. Coupled with this reduction of spread of pinaster to the north is the lack of suitable sites for colonisation compared to areas south of Bark Bay. This could help to explain why most of the younger pine growing at Long Valley appears to be the progeny of trees already established in the vicinity.

Here also arises another important factor involved in pinaster's dispersal and consequent invasion pattern. That is that it uses wind and the height of the area it is growing on to its advantage. From age samples, rapid long distance spread of pine has only become a major force in the invasion of pinaster since the mid 1940's, when it began spreading away from Bark Bay in greater numbers. It can be postulated that this time period roughly corresponds with the time that pinaster became established (mostly via stepped spread) on the hills above Bark Bay. Given this height advantage of 200 - 300 metres, it is possible that when strong winds occurred this additional height enabled pinaster seed to be carried greater distances before falling to the ground. This in turn could have a 'leap frogging' effect on pine dispersal up and down the coastal margin of the Park, where suitable sites were available for colonisation by pine. This is a theory only but could explain the rapid upsurge in dispersal of pinaster over long distances in the last 20 to 30 years.

It has already been stated that areas to the north of Bark Bay are more difficult for pine to establish compared with the south, due to the influence of prevailing winds and a small topographic barrier along with many unsuitable sites. But now that pinaster is becoming established in the Long Valley area it has gained a height advantage and even though strong southerly winds are not frequent, should they occur when seed is ready to fall, there exists a real potential of pinaster spreading on to any suitable sites further northwards.

It becomes imperative then that this stand is eradicated immediately to retard the spread in the northerly direction. This would stop the development of further seed sources of varying distances along the coast as has occurred south of Bark Bay.

The major effect of long range dispersal is that the species is no longer confined to a single area such as Bark Bay, but becomes dispersed throughout a large portion of the Park. From this the potential exists for increased invasion of new formerly pine free sites by pinaster where conditions are suitable. This is a consequence of the larger number of sites along the coast containing trees which may act as a seed source for further colonisation. Such seed should it be produced, has a high probability of falling on pine free areas and once established could in turn lead to colonisation of further new areas again so invasion could continue. From increment boring it is evident that long distance dispersal of pine has increased considerably since the mid 1940's especially south of Bark Bay. Given suitable colonisation sites,this represents a real danger to the Park,in that a rapidly expanding pine seed source will make any control programmes increasingly difficult.

In summary the two mechanisms of spread that were observed have been discussed in detail. Examples of 'long range spread' by pinaster over varying distances and in different directions, show that this mechanism of spread and the effects of colonies growing in size would significantly increase the rates of spread calculated from the five survey transects.

10. REGENERATION OF MARITIME PINE

It was commonly observed during the study that the majority of pine regeneration was confined to the Bark Bay vicinity and then it was mostly found in the L1 and more open L2 vegetation types where high, light conditions favoured its growth. It has already been established that

Plate13: Pinaster regeneration - juvenile growth form with characteristic adult double leaved foscicles beginning to develop. Shows affinity of the pine for bare open granite soils.

once a canopy had closed there was little chance of pinaster establishing itself due to insufficient light conditions. For this reason very little pine regeneration was observed within the P/B forest type or the denser and taller L2 types. In areas further away from Bark Bay, it was again only the open *Leptospermum* shrubland communities and more open sites which had pine regeneration growing on them.

An important observation that was also noted was the increase in pine regeneration once an older tree had fallen, inducing high light conditions on the ground. It was established that in 1975 as part of the Park's eradication programme, several pine had been felled on the island (Ranger Kilby, pers. comm.) in the Bark Bay Lagoon. (Plate 14). The tree visible on the photograph was established as being 39 years old. In the immediate vicinity of the felled trees where the relatively light Leptospermum cover had been broken, a total of 75 young regenerating pines were counted. From sectioning these

Plate 14: 'Island' - Bark Bay Lagoon - Felled pine arrowed.

stems and subsequent ring counts it was established that 85% of these were in the 0 - 2 year old age class. This indicated that these young pines were a direct result of the fallen pine increasing the ground light conditions and thus leading to an upsurge of pine regeneration to recolonise these sites. A similar effect was also observed in a canopy gap in the dense cover of pine behind Bark Bay Hut. (Plate 15). Here a wind-blown 59 year old pine had created a large canopy gap into which gorse and P. pinaster regeneration had readily invaded.

Approximately 35 juvenile growth form pines were counted within the gap obviously induced by the increased light conditions and abundance of seed. Occasionally similar evidence was also seen in canopy gaps caused by wind, but not of the significance of these two observations.

The inference that can be drawn from this is that any large scale felling programme that could be implemented to control the pine, could have the consequence of inducing open spaces into which pinaster regeneration may readily colonise again. This would only apply to the denser areas of pine as in the L1 types spaces already exist for colonisation by pine. Therefore, in such sites where pine was felled, it would be necessary to return after a period of two to three years to remove any regenerating pine and thus prevent the re-development of

Plate 15: Pine regeneration and gorse colonise a canopy gap created by the windfall of an old maritime pine behind Bark Bay Hut.

another subsequent source of seed. Occassional checks would also be necessary from time to time to ensure that the pine had been eradicated from such areas. Thus the main aim of this would be to prevent the build up of pine capable of producing seed once again.

11. MANAGEMENT CONSIDERATIONS

With respect to the situation of maritime pine in Abel Tasman National Park, many implications for management have been borne out in previous sections. In summation then, this section aims to gauge the threat of the pines to the Park and methods of combatting this threat.

11.1 Implications for Management

With the stipulation in the National Parks Act (1952) that "introduced flora and fauna shall as far as possible be exterminated" (S.3(2)), there are obviously important implications for management of National Parks arising from a study such as this. Obviously pinasters ecological features give it a clear competitive advantage over indigenous flora on certain sites within the Park. In particular, from the study, it appeared that the bare infertile soils and open *Leptospermum* vegetation types were most susceptible to invasion by pine. Many such sites exist along the coastline of the Park, especially between Marahau and Tonga Bay (Map 4) and one can forsee a real danger of pine invading into these sites before the somewhat slower natural reversion by indigenous species. This problem becomes further complicated by the ability of pinaster to establish outliers long distances from the original seed source. This means that the species is no longer confined to a single area, such as Bark Bay, but is sufficiently dispersed over a wide area to enable further spread given suitable conditions and sites. Importantly this rapidly expanding seed source will make any control operations increasingly difficult, as incidence of pinaster within the Park, becomes further widespread. It is imperative then to act quickly to control the spread of this exoitc species.

The aspect of fire also has an important influence on checking pinasters' spread. It is evident that many of the Parks shrubland communities are extremely vulnerable to fire damage, and indeed any burnt areas could have the adverse consequences of destroying any indigenous regeneration that might be present. This could effectively retard the succession to indigenous forest, while at the same time providing further sites for accelerated colonisation by pine. Furthermore the fact that pinaster is a resinous pine, and its inflammability making it an extreme fire hazard, especially in Nelson's dry summers, creates a further problem and emphasises the need to effectively control the spread of the species throughout the Park. Also fire in existing stands of pine can induce regeneration by opening serotinous cones as well as destroying indigenous regeneration. For these reasons it is imperative then, especially at Bark Bay which has the highest density of pinaster, that effective fire prevention and control procedures are maintained.

Given the danger that the pines pose to Abel Tasman National Park, clearly eradication would be the most ideal procedure to rectify the problem. Obviously limits of finance and labour, mean that such a task is not feasible given the current situation. Indeed the pine appears to be sufficiently well established to make total eradication a seemingly impossible task. For this reason then, it is important to establish priorities for control.

In certain cases it can be accepted that the pines are an integral part of the landscape and even have historical significance (e.g. Bark Bay). By keeping fire out of these areas, it would be hoped that eventually the indigenous vegetation may replace the pine. Advantageously pinaster is one of the more attractive conifers and in certain situations, such as the stand at Bark Bay, it does not appear to significantly detract from the scenic qualities of the area. In such situations then, the older established pine stands should be tolerated. On the other hand, single scattered trees, that clash visually and aesthetically with the native vegetation should be felled.

Highest and immediate priority though, should be given to retarding the spread of pinaster to new areas of the Park, so that seed sources do not become widespread, leading to further consequent invasion. It should be aimed then to eradicate all areas of pinaster other than those confined to the Bark Bay area (Map 3). In particular this would involve eradicating the pine at Long Valley to prevent the 'leap-frogging' pattern of spread northwards against the prevailing winds. Also the open shrubland areas south of Bark Bay should be watched accordingly (i.e. Falls River, Torrent Bay).

It is also hoped that many of the findings arising from this study may be equally applicable to the very similar radiata pine problem within the Park, although in many cases further detailed study would be required.

11.2 Control and Eradication

Methods of control that are available include the following:

1. Burning - not considered within a National Park.
2. Soil Sterilants - using herbicides applied to the base of trees.
3. Poisoning - injection of poison into stem.
4. Felling - pulling pine regeneration by hand or felling trees.

Both soil sterilants and poisoning are unsuitable as they are prohibitively expensive and give less effect on larger trees (Davenhill, 1974). In addition dead trees are left standing which would prove unsuitable in the Park situation. Felling then would appear to be the most suitable method of control or eradication. Obviously it is not possible to fell large areas of pine such as at Bark Bay due to the vast damage and consequent massive reseeding (Section 10), but if control of pine is to be an objective, effective felling procedures are required.

Priorities here, involve eradicating potential seed trees first and then younger pines. As it generally takes pinaster 10 - 12 years to produce fertile seed, the potential seed trees are usually emergents above the characteristically low *Leptospermum* shrublands, that they invade. This makes control easier in that it is only essential that the readily visible emergent trees capable of producing seed are felled immediately. Undoubtedly younger pines will exist in these shrublands which may be hard to find. As these trees are generally not capable of producing viable seed, then as long as they are felled immediately that they become discernible as they emerge from the shrubland canopy, there is no great danger of these trees contributing to further spread. Thus there is no great urgency in the total eradication of pinaster in areas where this is the desired objective, provided that any potential seed trees are removed. This then would require periodic control operations to totally eradicate pine from an area.

In checking spread away from Bark Bay, it has been deduced that major winds (i.e. greater than Force 6), during the seedfall period of pinaster (late summer/autumn) would lead to the greatest threat of further spread of pine. For this reason it is suggested that open shrublands and other likely sites for colonisation by pine,be surveyed for incidence of pine regeneration, in the direction of these winds,3 - 5 years following the occurrence of these winds. Areas requiring control operations could then be ascertained and the spread of pine checked. Control of pine could also be maintained by urging park-users to co-operate by pulling out any pine regeneration that they see. This could be achieved by defining the problem with respect to pines inthe Park, in brochures, illustrated lectures etc. and by displaying pertinent illustrations of the actual problem species (Plate 13).

Regarding the pine stands to be tolerated (i.e. Bark Bay) effective fire protection is essential if pines are to be eventually replaced by indigenous species. Indeed it may even be possible to accelerate this process of natural reversion of indigenous flora by planting shade tolerant indigenous species (e.g. rimu) within the stands of pine, so that eventually the pine is overtopped.

A feature unique to Abel Tasman National Park, is the co-operation that will be required by private property owners along the coast of the Park in order to maintain effective control of the spread of pine. As to achieving control, it is essential to eradicate pine from both National Park and private land simultaneously where required.

12. SUGGESTED AREAS OF FUTURE RESEARCH ARISING FROM THE STUDY

One of the major points arising from this study was the large number of unanswered questions in relation to pine in Abel Tasman National Park. These could all serve to highlight further areas of research. Such research would be essential before one can fully understand the processes occurring in this relatively unknown field which are so essential to the vast management of such an area.

One of the biggest questions remaining unanswered is the possible sequence of vegetation that will occur on these coastal vegetated areas as time progresses. European settlement of the coast has left many areas in an extensively modified condition. With National Park status the area is ensured of maximum protection to remain in an unaltered state. Already in many areas protected from fire and other man-induced changes, the slow process of reversion to native forest has begun. Thus, as a giant experiment in landscape recovery it could hold many answers of great human and scientific interest. Such problems to be solved are, will the pines be replaced by indigenous flora and the shrublands revert to natural forest, or will these vegetation types remain relatively static as time progresses? Can the pines and shrublands act as a nurse crop for indigenous species? In some of the denser areas of pine and kanuka, it would appear that the thick layer of very slowly decomposing pine needles along with low light sub-canopy conditions, would effectively prevent the establishment of many indigenous species. While on the other hand pine stands such as those at Coquille Bay and Tinline Stream show indigenous flora (including young Rimu) growing throughout. Similarly Ogle (1976) notes the increase in diversity of indigenous species resulting from the greater variety of 'micro-habitats' created by a variable density coastal stand of pinaster at Opoutoe, Coromandel Peninsula. Admittedly sites in Able Tasman are dramatically different to Coromandel, but the same principle could still possibly hold. Proximity of areas of pine to an indigenous seed source and sufficient penetration of the canopy by light, could explain why some of the stands have indigenous vegetation growing within them while others do not. Many of the moister gullies appear to have a predominantly hard wood vegetation (Mahoe, Kamahi, Marble leaf) in them. The presence of species with palatable drupes in these gullies could attract frugivorous birds, which may in turn disperse seeds of these indigenous species throughout the pine and shrubland areas. Small kamahis were occasionally seen within the L1 vegetation type and here the possibility arises that the L1 type may just be an early stage in the succession through to the L2 type and thence the P/B type. Regardless of these observations though, it is unwise to infer what the eventual succession of both exotic and indigenous species will be without firm quantitative data to back up such observations. Here arises the need for further scientific research in order to quantify many of these aspects. Methods of comparison of indigenous and pine regeneration inside pine stands as well as outside, could serve to provide some of these answers.

Other aspects into which future research could be beneficial to understand the processes occuring within the Park are detailed as the following:

1. A knowledge of the infertile low Leptospermum shrublands (i.e. L1 vegetation types) would be essential to understanding the succession that may occur on these sites. Has an original forest cover been removed, perhaps by early Maori burning, with consequent loss of topsoil and very slow recolonisation of the infertile subsoil, or are these areas true natural shrublands, their vegetation able to survive conditions of such low fertility that forests were not able to establish? Attempts during this study at answering this same question failed and it is obvious that a more detailed study would be required before any firm conclusions could be drawn.

2. This study was confined solely to P. pinaster within the Park but P. radiata is also present in even greater numbers over a greater area. Could it be that aspects of this study could be relative to P. radiata as well? A similar study on Radiata Pine would provide such answers, although present indications are that the two species could be very similar in habit, i.e. occupying the same vegetation types, similar methods of dispersal, etc.
3. Ecological aspects of P. pinaster also require further study to develop a better understanding of the invasion characteristics of such colonising pines. As has been noted in a previous section, no information could be found regarding the occurrence of inbreeding within P. pinaster as could quite possibly be occuring within some of the colonies that were observed. Also does Maritime Pine have better seed years some years than others, and if so what causes such prolific seed years? Is there any inherent periodicity associated with P. pinaster seedfall? An important question that could not be answered is the time of year seedfall actually occurs in the Southern Hemisphere, and with P. pinaster being a semi-closed cone pine, what conditions lead to and how long does it take for seed to be released from pine cones? Obviously very little is known about P. pinaster in the New Zealand context and information in any of these fields would aid a better understanding of both P. pinaster and features of invasion by such colonising pines.

It is also noted that should the pines at Bark Bay be left, as would appear the practical case, they have a definite intrinsic value for research purposes in studying the ecology of a colonising species in great detail. As such they provide a classic example of invasion from approximately 70 year old trees right through to seedlings, in a radiating pattern outwards from the seed source. Further study here could quite possibly benefit the knowledge of invasion by exotic pines and the types of land and vegetation types that they readily invade into. For this reason if any pines were felled as part of a pine control programme, it would be most worthwhile to record data on age, size, location, etc. Such data if collected, could prove valuable for future research into invasion characteristics of exotic pines. An aspect that should be persued following this study,are recordings of any new of additional areas omitted in this study,where P. pinaster has become established. This would aid in mapping up-to-date distribution of Maritime Pine within the Park and determining areas where control was necessary.

Another important area sadly neglected in this study, due to time and practical limitations was:

- An accurate survey of the density of pine distribution throughout the Park.
- Determining the age when P. pinaster first produces fertile seed.
- Relation of soil types to invasion by pine.
- Incidence of cone setting.

13. CONCLUSION

From this study it is clearly evident that maritime pine has a very real potential to expand its distribution dramatically, and if left unchecked, it could drastically modify the present coastal vegetation and landscape in the southern portion of Abel Tasman National Park. Although total eradication is not a feasible objective, some form of control is obviously necessary to stem the spread of pinaster, before it creates further problems. To this end then, a number of recommendations have been made:

1. That maritime pine be accepted as part of the landscape at Bark Bay and confined to the immediate environs of that Bay.
2. That maritime pine be eradicated from those areas of the Park other than Bark Bay into which it has spread and colonised.
3. That the public be made aware of the danger and damage that fire can cause, in the coastal shrubland communities of the Park and in the stand of maritime pine at Bark Bay in particular.
4. That the public be encouraged to pull-out, fell or destroy any pine regeneration when they encounter it.
5. That further research be undertaken to improve our understanding of these natural processes occuring within the Park.

This study as such, has dealt with just one aspect of the natural processes occuring within Abel Tasman National Park. Admittedly many of the observations do lack firm quantitative evidence, but they do uncover areas that require further investigation and illustrate that we cannot keep our unique landscapes by closing them up. Instead we must understand the processes going on within these landscapes and use this knowledge to maintain then in a condition compatible with our aims for National Parks.

ACKNOWLEDGEMENTS

Acknowledgement is made, with gratitude to Professor P.J. McKelvey and Dr. J.E. Barker (School of Forestry, University of Canterbury) for guidance and criticism throughout this study; to Messrs. G. Walls and K. Hackwell (Botany Division, D.S.I.R., Nelson), for constructive criticism of the survey method; to the Meterological Service (Wellington) and the D.S.I.R. Tobacco Research Station (Motueka) for climatic data pertaining to the study; to Lands and Survey Department (Nelson), for use of maps and aerial photographs; and to Mr. B.D. Andrews (Lands and Survey, Hokitika), for draughting of maps 3 and 4. Thanks are also due to the following who unselfishly gave of their time, recollections, letters and photographs to assist with respect to the historical section of this study; Mr. A.S. Bagley (Nelson Provincial Museum), Mr. M.L. Gibbs (Nelson), Mr. F. Holyoake (Motueka), Mr. E.O. Host (Nelson), Mrs. P. Moncrieff (Nelson) and Mr. J.H. Wildermoth (Christchurch). I am also indebted to the financial assistance provided by the Owen Browning Trust Fund, enabling me to undertake this study, and in addition the author is indebted to Mrs. N. Mann for typing the manuscript.

Above all I would like to thank the staff and members of the Abel Tasman National Park Board, without whose generous assistance this study could never have been accomplished.

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NATIONAL PARK

ABEL TASMAN NATIONAL PARK BOARD

All Communications to be
Addressed to the Secretary

BOX 443,
NELSON.

Please quote
AT 49
in your reply.

3 February 1978

Mr Lewis Sanson
128 Lyttelton Street
CHRISTCHURCH 2

Dear Sir

MARITIME PINE SURVEY

This is to confirm in writing the verbal approval already given to you by the Board to carry out a Maritime Pine Survey along the coast of the Abel Tasman National Park between the dates 10-20 February 1978.

You are to discuss this matter in detail with the Chief Ranger and you are to keep staff informed at all times of your movements.

Yours sincerely

L ~~H~~ RUSSELL
Chairman

D.S.I.R.
Tobacco Research Station
R.D. 3,
MOTUEKA.

APPENDIX I·2 SUMMARY OF CLIMATIC DATA 1976-1977

			Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July
RAINFALL mm		1976-77	175	116	126	151	234	51	102	22	83	87	205	195
	Normal	1941-1970	140	117	112	89	91	74	99	104	127	155	119	145
AIR TEMPERATURE °C														
Mean Daily Maximum		1976-1977	12.9	14.4	15.9	17.9	21.0	21.7	22.5	22.3	19.2	14.2	12.8	12.4
Average		1956-1975	13.6	15.7	17.9	19.8	21.9	23.2	23.4	21.5	18.8	15.8	13.5	12.5
Mean Daily Minimum		1976-1977	2.5	4.6	6.6	8.5	10.7	11.6	11.7	10.6	7.3	4.5	1.7	1.3
Average		1956-1975	2.5	4.8	6.7	8.7	10.7	11.7	11.9	10.5	7.5	4.6	1.8	1.2
EARTH TEMPERATURES °C														
	0.10m	1976-1977	5.7	8.0	11.7	13.6	17.0	16.7	17.4	16.4	11.2	5.3	4.2	5.1
Average at	0.10m	1956-1975	5.5	8.8	12.3	15.8	18.4	19.7	19.0	16.0	11.9	7.8	4.6	5.8
	0.30m	1976-1977	8.1	10.4	12.9	15.3	19.0	19.3	20.5	19.0	14.8	8.7	6.7	7.2
Average at	0.30m	1956-1975	7.5	10.6	13.8	16.8	19.6	21.3	21.2	18.4	14.4	10.4	6.8	5.8
	0.91m	1976-1977	8.9	10.3	12.5	14.1	16.7	17.7	18.5	18.4	16.5	12.4	9.7	8.8
Average at	0.91m	1956-1975	8.7	10.5	12.8	15.2	17.3	19.1	19.8	18.7	16.4	13.3	10.2	8.3
SUNSHINE HOURS														
		1976-1977	145	161	182	215	230	226	245	211	192	191	112	128
	Normal	1941-1970	185	205	227	244	252	268	236	222	195	165	150	153

APPENDIX 1.3

LOCATING THE INITIAL SEED SOURCE WITHIN ABEL TASMAN NATIONAL PARK

It had been hoped to confirm by increment boring, the historical evidence that the oldest pinaster in the Park (therefore, the assumed initial seed source) were in fact the pines growing on the "Homestead Flat". Unfortunately though, many of these trees had a larger diameter (i.e. greater than 80 cm inside bark diam.) than the maximum reach to include the pith of the largest increment borer, (i.e. 40 cm) even with bark chipped away. For this reason ageing by increment core ring counts was not possible on these trees. In contrast all other trees encountered, other than those on "Homestead Flat" were within the reach of the increment borers giving a possible indication that the flat was indeed the probable initial seed source of pinaster in the Park.

Fortunately there were several windfall pines on the flat, from which actual ring counts (from chainsaw cuts) were possible. In addition all maritime pine on the flat was measured for height and DBH (Table 1).

Tree number	DBH (cm)	Height (m)
1	110	19
2	119	felled
3	109	20
4	112.5	felled
5	89	17
6	86	15
7	97.5	19
8	96	19
9	72	17
10	84	20
11	82,5	19
12	80	18
13	57.5	15
14	80	19
15	97.5	20
16	92	18
17	81	18
18	82	18
19	79	16
20	81	18
21	76	14

Table 1: Height and DBH of Pinaster on "Homestead Flat"
Mean DBH = 88.74 cm Mean Height = 17.32 m

It was deduced that the four largest pines (trees 1-4) may possibly be the oldest pinaster in the Park. Fortunately, two of these were felled and from ring counts the age at the 25cm sampling height was estimated to be 70 years. Using the age/height relationship (Appendix 5.1) the true age of these oldest pines could be approximated as 72-73 years (i.e. planted 1905-1910).

Mean DBH = 112.63 cm

Mean Height = 19.5 cm

It was presumed then that these pines were indeed, the initial seed source of P. Pinaster within the Park.

APPENDIX 1.4

VEGETATION TYPES

For the purposes of this survey the Leptospermum shrublands described in Section 2.2 were broken into two distinct sub-types. Also the Beech and Podocarp/Hardwood forest type. Amalgamated into one type - the Podocard/Hardwood/ Beech type due to the relative resistance to the invasion of the type by pine. The occurrence of pine within a type was generally ignored at this stage of the survey so that it could be determined which vegetation type(s) that the pine was advancing into. These types were derived initially from aerial photographs and then subsequent checking in the field. All three types are shown on the aerial photographs in Appendix 9.2 and on map 4.

1. Leptospermum Type 1 (L1)

This is essentially a low open Leptospermum (Tea Tree) shrubland type. Manuka (L. Scoparium) is the dominant species but is almost invariably accompanied by Kanuka (L. ericoides) on the more fertile sites, and those not exposed to coastal winds, as it is less tolerant than manuka of saline winds. (Esler, 1974). The type is generally distinguished from the L2 type by vegetation rarely exceeding 3 metres in height and is essentially a lowland shrub association growing on characteristically infertile and impoverished skeletal granite soils. Mingimingi (Cyathodes juniperina and C. fasciculata) generally occurs throughout, in association with Pimelea gnidia stunted kamahi (Weinmannia racemosa) and occasional Dracophyllum urvilleanum were also observed on some sites. Dispersed throughout the type are large Gahnia spp. tussocks, along with Lycopodium scariosum, L. volubile, Cladium vaulthera, Dianella intermedia and occasional Libertia grandiflora, Phormium cookianum and Astelia spp. Three ground orchids, Dendrobium cunninghamii, Earina autumnalis and E. mucronata also occur on the well drained, bare granite soils. A measure of the infertility of the thin granite soil occupied by the type is the virtual absences of grasses, the spaces between taller plants being occupied by mosses and lichens such as Cladia

Plate 16: Leptospermum Type 1 (L1) - characterised by low manuka scrub and Gahnia grass. Note the emergent P. pinaster (Bark Bay Headland)

retipora and Usnea spp. The type is also characterised by the presence of the exotics, Hakea acicularis and H. saligna along with gorse (Ulex europaeus) heath (Erica lusitanica) and the pines, P radiata and P. pinaster). Vegetation usually covers no more than 20 - 30% of the ground area and large outcrops of granite rock are common.

2. Leptospermum Type 2 (L2)

Characteristically taller than the L1 type, (i.e. greater than 3m in height) this vegetation type is usually found on the lower more fertile sties. It can also be distinguished from the L1 type by the presence of a shrub/ hardwood, fern understory. Kanuka is the prominent species occurring in association with occasional manuka stems. Canopy heights of up to 12m are common. Shrub/hardwood species typically found consist of heketana (Olearia rani), kamahi, the two Cyathodes spp. in abundant numbers, Coprosma spp., Pseudopanax spp. marble wood (Carpodetus serratus), horopito (Pseudowintera colorata and P. axillaris), manhoe (Melicytus ramiflorus). Other species occasionally evident are toro (Myrsine salicina), tarata (Pittosporum eugenoides), pigeonwood (Hedycarya aborea), hutu (Ascarina lucida) and on those sites close to the sea, Kawakawa (Macropiper excelsum) and ake-ake (Dodoneae viscosa). Hakea spp. are also found close to the coast.

Plate 17: Leptospermum Type 2 (L2) - characterised by a shrub/hardwoods with many ferns. Note higher shade conditions (Homestead Flat).

3. Podocarp/Hardwood/Beech Type (P/B)

The P/B areas can be broadly described as those areas not covered by the Leptospermum vegetation types. These are principally valley floors, lower slopes along the coastal margin and extensive areas are found further inland. The type includes both pure beech, podocarp, hardwood and mixed stands. The type as such, is extremely broad and the reason for combining a number of types into one, is that due to insufficient sub-canopy light conditions, pinaster is not actively invading into these types and does not appear to pose any problems within the type. The characteristics of the type have already been boradly described in Section 2 but briefly it consists of 20-30m emergent beech and podocarps (principally red beech and rimu) over a 10-15m hardwood component matrix.

Plate 18: Podocarp/Hardwood/Beech Type (P/B) Note the emergent red beech and rimu over a predominantly hardwood/fern sub-canopy (Huffam Stream).

The major hardwood species comprise rata (Meterosideros umbellata) kamahi, (Quintinia acutifolia) mahoe, pigeonwood, tarata, pokaka (Eleaocarpus bookerianus) and broadleaf (Griselinia litteralis). Rata and kie-kie vines (Freycinetia banksii), bush lawyer (Rubus spp.) and supplejack (Rhipogonum scandens) are also commonly present beneath the hardwood sub-canopy. Ground and tree ferns are abundant on moister sites, (e.g.) mamaku, (*Cyathea medullaris* black ponga, gully fern and wheki fern (*Dicksonia squarrosa*) nikau palms (*Rhopalostylis sapida*) and pukatea (*Laurelia novae-zelandiae*) can be occasionally found in lowland gullies. The forest floor contains ground ferns, seedling trees and shrubs, plus a rich assemblage of mosses, liverworts and fungi all growing amongst the dense leaf and twig litter.

Generally the type has the appearance of a rich and diverse flora with active replacement trends occuring throughout.

APPENDIX 2.1

TRANSECT LOCATION

Line transects with systematic sampling points were the basis of the survey and were chosen on the basis of demonstrating what initial observations from aerial photos and a recce survey indicated was occurring. From the recce survey it was evident that the largest trees and apparently the oldest from historical evidence, were those growing on the coastal flat on the true right of Bark Bay ("Homestead Flat"). The assumption was then made that these being the initial seed source of pinaster in the Park, all transects had to begin on these flats.

A base line of 295^{o} mag. (Appendix 9.1) was established at Bark Bay, being the base of the hill where it ran out onto the Homestead Flat. All transects used in sampling for age were then started at predetermined intervals along this line and plots were sampled in a regular interrupted form along the transect.

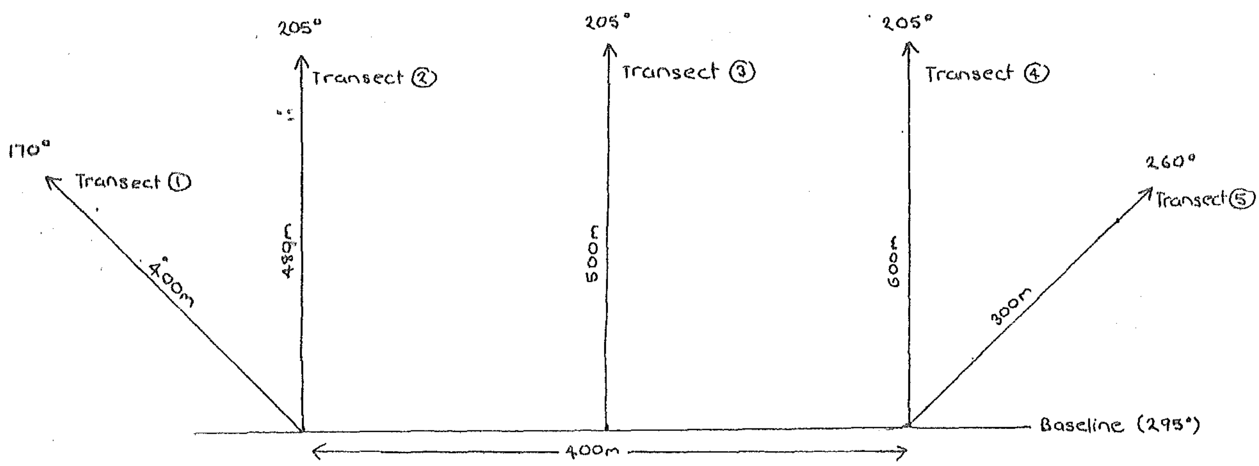


Fig. 1: Transect Dimensions

It was observed that the general spread of the pines away from Bark Bay appeared to be in a S.W., S.S.W. direction up off the Homestead Flat (Plate 5). For this reason it was proposed to run transects in these approximate directions where the spread of pine appeared to be most concentrated.

Line transects were initially plotted on aerial photos (Appendix 9.1) with the predominant consideration being that transects should pass through areas of pine for as long as possible, in order to make effective rate of spread estimates possible. Five transects were decided on, each transect to be sampled identically and located as follows:

1. Three transects were located approximately equidistance apart and at right angles to the main contours, in a south westerly direction (i.e. Transects 2, 3 and 4, Bearing = 205^{O} mag.)
2. One transect was located in a southerly direction (transect $1/170^{O}$)
3. One transect was located in an easterly direction (transect $5/260^{O}$)

The transects were to extend until they ran out of pine (i.e. inevitably the change in forest type to P/B). Magnetic compass bearings were taken from aerial photos for each transect.

Comment

The transect approach to sampling is usually followed where there is a readily observable gradation in vegetation in relation to a marked environmental gradient (Shimwell, 1971). It was deduced that this appeared to be the case with a succession of pinaster age classes immediately south of Bark Bay and transects were so located to confirm this feature.

APPENDIX 2.2

MEASUREMENT OF PLOTS

Once the compass bearing and starting point of individual transects had been determined along the base line, sample plots were established at 50 metre intervals along the transect until one ran out of pine (usually 600 m max). The 50m distance between consecutive plots was determined using a 25m nylon running line.

Each sample plot consisted of sampling the four largest trees within a 10m radius of the plot centre, this being designed to improve the probability of sampling the four oldest trees on the plot. The larger trees selected were to be generally representative of the surrounding pine

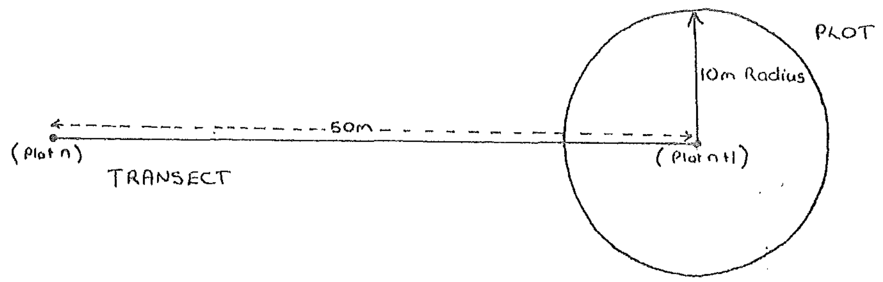


Fig. 1: Diagramatic Representation of Sampling

so that it would be possible to assess the rate of spread away from the assumed initial seed source by estimating the mean oldest age of pine on each plot. The first plot on each transect began on the base-line. Details of each plot were recorded in the field on "Increment Core Data Sheet I" (Appendix 3.1).

Information recorded for each plot on the data sheet was as follows:

A. Site Factors

A number of different factors were recorded to relate to the age distribution of pine.

1. Altitude - measured with a barometric altimeter to the nearest 10m (Altimeter calibrated at sea level

each day).

2. Aspect - Measured at right angles to the general lie of the plot to the nearest 5^{o} mag.

3. Slope - Average slope of land to the previous plot measured with a Suunto clinometer to the nearest 5^{o}. Readings were taken at right angles to contours and subsequently used to calculate true horizontal distances.

4. Physiography - Recorded as one of 4 physiographic land forms: Ridge (R)/Force (F)/Gully (G)/Terrace (T).

5. Canopy Height - Recorded in metres as an estimation of the height of the dominant canopy species above the ground.

6. Dominant Species - Denoted the major species comprising the canopy.

7. Pine Density - This was a subjective estimate of the pine growing on each plot, characterised according to the basal area cover of the area. Pine > 2m was divided into one of three density types:

   Dense (D) = 101^{+} stems/hectare
   Medium (M) = 11 - 100 stems/hectare
   Sparse (S) = 1 - 10 stems/hectare

8. Vegetation Types - The vegetation on each plot was classified into one of the three vegetation types earlier established (Appendix 1.4)

   L1 = Leptospermum Type 1
   L2 = Leptospermum Type 2
   P/B = Podocarp/Hardwood/Beech Type

B. <u>Sampling of Pines</u>

For each of the four largest most representative trees within a 10m radius plot, four different variables were recorded:

1. Age

   Recorded according to method in Appendix 2.3.

2. Sampling Height

Where a tree had a distance greater than 25cm on the downhill side of the tree, to the point where the increment core was extracted, the distance was recorded as the sampling height (this generally occurred with trees growing on slopes). This was used to compare all tree ages in relative terms. If the sampling height was 25cm above the uphill side of the tree, as was usually the case, this space was left blank.

3. Diameter Breast Height (DBH)

DBH was measured on the uphill side of trees as an over-bark diameter at a point 1.4m above the ground.

4. Height

The height of each tree sampled for age was recorded in metres. On the first plot and every subsequent five plots a Suunto clinameter was used to gain a height estimate, while on alternate plots subjective estimates were made.

NOTE: If a tree appeared to be marginal as to its inclusion in the 10m radius plot, then a 10m line was run from the plot centre to the tree in question. If greater than half the trunk was within the plot, the tree was counted as 'in' for the purposes of this survey.

C. Notes

Here were recorded any significant features about the plot being sampled or area through which the transect had passed since the previous plot, e.g. regeneration, soils, mortality, etc.

Comments

1. The reason that the four closest pines to the plot centre were not sampled rather than the four largest trees, was that in the more dense stands of older pine there was often significant numbers of pine regeneration that could have given a false indication of the results of the mean oldest age of pine on each plot.

2. The measurement of the four largest most representative trees was also designed to avoid the problem of measuring the spread from outlying parental trees (i.e. outliers) and enabled concentrated measurement of the general rate of spread from Bark Bay. It should be noted though, that if pine regeneration was one of the only four pinaster on the plot, then and only then was its age recorded.

3. Generally there were always at least four pines on each plot, as the transects were purposefully located to follow

areas of pine for as long as possible. It was usually only at the extremeties of pinasters present distribution immediately south of Bark Bay, particularly in the transition to P/B vegetation type, that the number of trees per plot fell below four. It was also observed that there were very few pines on the base-line. This was the only major anomaly in age class distribution of pinaster and both these factors were taken into account when calculating rates of spread.

4. Plots closest to Bark Bay were generally on the steepest country and therefore the majority of these trees were sampled at a height greater than the 25cm standard. The actual sampling height for these trees was recorded and an allowance was made to make their ages consistent with all other sampled trees (Appendix 5.1).

APPENDIX 2.3

SURVEY OF PINE OUTLIERS

Groups of pine outliers or colonies were identified on the aerial photos (Appendix 9.2) and in addition to the survey of rate of spread, a survey was also carried out of each of the major outliers. Increment Core Data Sheet II (Appendix 3.2) was used to record data for each outliers. Each outliers visible on the aerial photo was in turn located on the ground and the ten largest trees were aged from the increment cores taken at the standard 25cm height. (Refer Appendix 2.4). This gave the oldest tree in each outliers which gave an indication as to when the outliers may have begun. This in turn could possibly be related to the timing of any strong winds in the direction of the pine outliers away from the supposed seed source (i.e. Bark Bay).

APPENDIX 2.4

AGEING OF PINES

With the impractibality of the most ideal method of felling trees at ground level to count successive growth rings, two different techniques were employed to estimate ages of trees sampled.

1. Trees shorter than 2 metres

Trees less than 2m in height sampled, were cut at ground level and also at 25cm height. Both ages were recorded from actual ring counts (columns 2 and 3 respectively, Appendix 3.1), and a cross (x) was beside the tree number to denote that it had been cut at ground level. DBH's for these trees were not recorded and where seedlings shorter than 25cm were recorded (i.e. regeneration) only the approximate ground height was noted.

2. Trees taller than 2 metres

Ageing of pine greater than 2m in height necessitated the use of an increment borer to extract increment cores at the lowest possible point on the tree bole. From these cores successive growth rings were counted to gain an estimate of tree age. To reduce error in ring counts two increment cores were taken from each tree. These were taken on the circumference of each tree bole as shown in Fig.1.

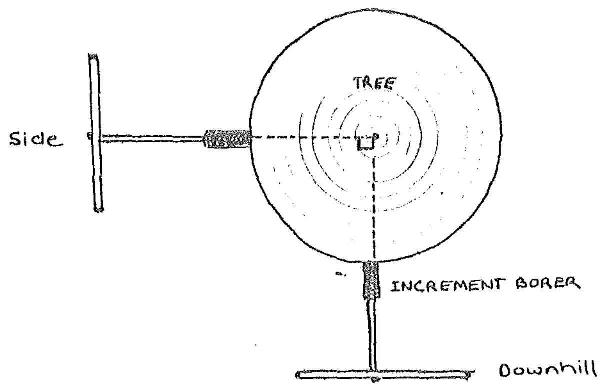


Fig. 1: Location of Increment Boring on Circumference of Tree

To gain consistency in the data it was postulated that cores should be extracted at an identical height on all trees. This would in effect give a relative age between sampled trees that could be readily interpreted in data analysis. The actual tree age could then be approximated where necessary, bearing in mind that all samples were taken at a constant height (Appendix 5.1). The uniform sampling height decided upon was in effect, the minimum turning radius above the ground of the largest increment borer used on the survey (Plate 6). To maintain consistency between trees growing on flat and sloping ground, the sampling height chosen was a height 25cm above the ground on the uphill side of each tree and at right angles to the tree's bole (Fig. 2). The vertical distance on the downhill side from the position of increment boring to the ground was recorded only if it exceeded 25cm (column 4, Appendix 3.1) under the heading sampling height. This was in order to make an allowance for sampling height and so keep tree ages in relative terms by using the age/height relationships

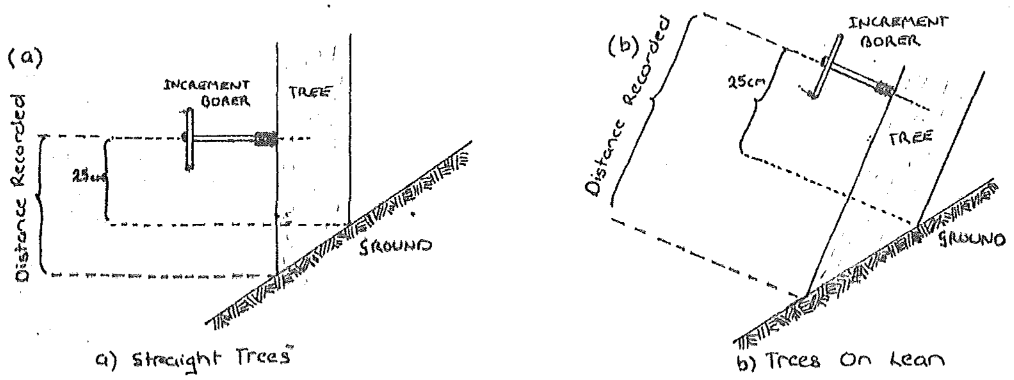


Fig. 2: Increment Core Sampling Height

calculated in Appendix 5.1. If trees were leaning at all, the sampling point was still at a height 25cm above the ground on the uphill side of the tree, but the core was taken at right angles to the bole of the tree (Fig. 2b).

Once increment cores were extracted that included the pith, the successive earlywood/latewood growth rings were counted to gain an estimate of tree age. Cores were generally double counted in the field due to the problems of collecting and storing cores (i.e. breakage). A field hand lens was carried to aid ring counting and indistinguishable cores were wiped with oil to help accentuate growth rings. The pith was counted as year 1 to maintain consistency in ages. Increment cores on which it was very difficult to carry out ring counts in the field (due to proximity of growth rings) were collected and brought back for age assessment using the School of Forestry's electronic ADDO-Ring Counter. In such cases a tick (✓) was placed beside the tree number and a label detailing transect, plot and tree number was attached to the core. Cores were then placed inside a large milkshake straw to prevent breakage during transit.

Being in a National Park it was aimed to keep any damage to vegetation to a bare minimum. This was especially required for the large pines along the track at Bark Bay which could provide a danger to trampers, as well as looking aesthetically displeasing, should they be killed from pathogenic attack of core holes while still standing. For this reason all holes caused by increment boring on the readily visible larger pines were filled with "grafting matrix", (a wax containing Capitol fungicide to prevent entry of disease and insects and to promote healing).

Comments

1. The distinct advantage in ageing pinaster from increment cores are its well defined annual growth rings. The yellow/ white earlywood embodied by the red/brown latewood makes it relatively easy to determine successive years of growth. Generally I counted the darker late wood rings and as only earlywood had been produced for the 1978 year when I carried out my survey, I extrapolated this single earlywood ring as being one year of growth. The only problems in estimating tree age from the increment cores were sometimes indistinct growth rings and occasionally yellow resinous wood obscuring all evidence of annual growth rings. In this case I kept boring until a clear core was obtained. Some cores from larger trees also had a tendency to coil up and break once

extracted from the tree; this appeared to be due to the presence of tension wood and in these cases I usually sampled on the opposite side to obtain a distinct core.

2. With increment boring to determine the age of a tree, the major problem lies in including the true pith of the tree in your core. To begin with, I took many more than two borings per tree, that I required, but the majority were rejected until a core included the pith. It was generally found that the older and somewhat larger trees were the most difficult to bore and extract a core combining the pith. But from the first core one could generally determine the approximate direction of the pith by looking at the curvature of the inner growth rings. Using this principle it became easier with practice to determine where the pith was and with trees having a DBH less than 45cm, it became relatively easy to hit the pith on the first boring.

3. The presence of false growth rings in the trees sampled was also not discounted. It has been shown that periods of drought often induce false growth rings in *P. pinaster* (Scott, 1962). With the often drought prone granite soils of the coastal area of Abel Tasman National Park, it becomes evident that the presence of false growth rings could be a distinct possibility in the pine sampled. For this reason two cores per tree were always taken to provide an added check on the validity of the data. To this end it was found that of the variation that occurred between the two growth ring counts for each tree, most was in the older and consequently larger trees.

4. Generally there was less variation between the two ring counts for younger and smaller trees. For this reason it must be noted that the recorded ages are estimated only of the tree age and as they were all taken from samples above the ground on the tree, it should be borne in mind that they only give a relative indication of the age structure of the *P. pinaster* population. Any attempts at estimating the true age of the trees must consider age and height up tree that the sample was taken.

5. Most trees were generally of good form and therefore relatively easy to sample but occasionally problem trees were encountered within a plot. Trees encountered with multiple leaders, buttresses and deformations of any type, tended to upset the survey method being used as usually one was unable to take an increment core at the standardised 25cm heigh sampling position. In all these cases where it was impossible to sample at the 25cm standardised height, I sampled at the lowest possible point where I could get a true representation of tree age. This was invariably at a height greater than 25cm so the height from the core to the ground was recorded on the data sheets. Age/height relationships (Appendix 5.1) could then be used to try and determine an age relative to all the other trees sampled at 25cm. It was also advisable to avoid bark encased branches and knotty wood as far as possible, but generally the 25cm sampling height was low enough to miss most branches.

6. Another problem encountered in increment boring P. pinaster is the very thick platey nature of its bark. This can create problems on larger trees where the tree radius is greater than the 40cm reach of the largest increment borer I had. There were relatively few of these such trees and in all cases the bark was chipped away to leave a minimum protection covering over the tree and then the increment core was taken.

7. Increment boring on the very largest trees was impossible due to the maximum core length from the increment borer at some 40cm. Fortunately these trees were very few (i.e. 100cm DBH) and most were located on the "Homestead Flat". Here I had the advantage of having several of these trees already felled and from a chainsaw cut I was able to gain a relative idea of the age of these oldest trees which presumably were the original seed source.

APPENDIX 3.1

AREA Bark Bay | INCREMENT CORE DATA SHEET I | LINE 3 100

DATE 15/2/78 | ABEL TASMAN NATIONAL PARK | BEARING 205° mag

PLOT 9	ALTITUDE 250m	ASPECT 45°	SLOPE 20°	PHYSIOGRAPHY F
	CANOPY HT. 3m	DOM. SP. Konuka	PINE DENSITY M	VEG. TYPE L1

NOTES Low Konuka with scattered emergent pines (Photo taken of plot) Photo ref = 1/13
granite outcrops occur among a predominantly bare, exposed granite skeletal soil with a v. thin (1cm) litter layer — not decomposing. *Uncinia uncinata* is the only other vegetation present. Pines here appear more exposed to coastal salt winds, ⇒ hence large DBH but short height?

TREE	AGES		SAMPLING HT.	D.B.H.	HT.
1	30	30	25	42.6	10
2	19	19	25	25.3	9
3 ✓	32	33	50	31.5	8
4	25	25	25	33.0	9

PLOT 10	ALTITUDE 275m	ASPECT 45°	SLOPE 20°	PHYSIOGRAPHY F
	CANOPY HT. 3m	DOM. SP. Konuka	PINE DENSITY M	VEG. TYPE L1

NOTES More open than previous plot with v. little pine regen.
Again trees have a fat, short appearance.
v. skeletal soils with coral lichen ( ) and Uncinia the only vegetation.
From cores, these trees appear to have a v. slow increment up to age 22-25

TREE	AGES		SAMPLING HT.	D.B.H.	HT.
1	24	24	25	42.0	10
2	26	26	25	31.6	8
3 ✓	30	30	25	30.9	7
4 ✓	29	28	25	38.6	8

PLOT 11	ALTITUDE 290m	ASPECT 90°	SLOPE 25°	PHYSIOGRAPHY F
	CANOPY HT. 2m	DOM. SP. Konuka	PINE DENSITY S	VEG. TYPE L1

NOTES v. open shrubland - tea tree the only vegetation with occasional emergent pines.
- one large (10m) dead "pine seen" with wasp nest in it. - right on crest of ridge to right of transect (Photo Ref 2/6)

TREE	AGES		SAMPLING HT.	D.B.H.	HT.
1	24	24	25	19.7	6
2	27	28	25	34.2	7
3	23	23	25	28.5	6
4	26	26	25	32.4	9

PLOT 12	ALTITUDE 300m	ASPECT 10°	SLOPE 5°	PHYSIOGRAPHY T
	CANOPY HT. 1.5m	DOM. SP. Konuka/Kanuka	PINE DENSITY S	VEG. TYPE L1

NOTES This plot falls on the crest of the v. broad ridge above Bark Bay
v. open shrubland community with a lot of bared white granite soil
- occasional large pines but quite a lot of pine regen evident.

TREE	AGES		SAMPLING HT.	D.B.H.	HT.
1 ✓	28	28	60	41.1	13
2	23	23	25	22.8	6
3	14	14	25	17.8	4
4 ✗	8	6	cut	1.1	1.5

APPENDIX 3·2

INCREMENT CORE DATA SHEET II

ABEL TASMAN NATIONAL PARK

AREA Long Valley Creek **DATE** 17/2/78

DESCRIPTION Colony 10 Veg Type : L1

Lies right on seaward side of track at head of Long Valley Creek

TREE	AGES		SAMPLING HT	D.B.H.	HT.
presumed founder tree	48	48	25	68·5	16
1	36	37	25	45·2	13
2	33	33	25	32 4	11
3	32	32	25	42·3	12
4	28	28	25	25·6	10
5	28	28	25	24·3	9
6	27	27	25	31·2	11
7	23	23	25	30·3	8
8	22	22	25	24·2	8
9	23	23	25	27·3	9
10	21	21	25	20·1	7

2 photos taken of colony ·(Ref. 2/17 + 2/18)

One of the largest colonies encountered, founder tree readily visible as a fairly large tree overtopping presumed offspring.

Note v. small sizes of the majority of colony trees c.f. open grown trees – probably as a result of intense competition within the stand.

Colony is on a dry, well drained granite soil site directly adjacent to a gully. Appears to be a lot denser than colony 9 with a larger proportion of younger age classes. The younger trees form a definite ring in graduating age classes outwards around the founder tree.

- v. little regeneration of any kind within the colony, indeed there exists a v. thick carpet of pine needles everywhere
- many of the stems inside the colony are v. spindly and thin also many are dead or dying and being overtopped by other pines through the effects of intense competition

APPENDIX 4.1

Plot Sheet Summary

Transect 1

Bearing 170°

16.2.78

PLOT	NO. TREES	MEAN AGE (yrs.)	MEAN DBH (cm)	MEAN HT (m)	CUMM DIST	SLOPE (°)	ALT (M)	ASPECT (°)	PHYSIO	CANOPY HT.	DOM. SP.	PINE DENSITY	VEG. TYPE
1					0	5	0	20	F	9	SH/ kan		L2
2	4	56.3	75.6	18.8	41	35	40	20	F	12	"	M	L2
3	4	54.0	72.4	18.4	82	35	80	25	F	18	Pine	O	L2
4					127	25	70	55	G	6	SH		L2
5	4	42.0	44.6	14.3	173	25	100	335	F	6	Kan	M	L2
6	4	40.5	44.6	13.3	221	15	125	30	F	6	Kan	M	L2
7	4	28.3	41.4	11.0	270	10	150	35	R	6	Kan	M	L2
8	4	25.5	39.1	10.5	318	15	125	225	F	10	Kan	M	L2
9					367	15	110	140	G	12	SH		P/B
10	4	3.0	2.5	0.3	416	10	140	140	F	3	Kan	S	L1
11					465	10	130	110	G	25	P/B		P/B
12	4	29.3	43.0	10.8	510	25	175	20	F	12	Pine	D	L1
13	4	29.8	34.3	10.0	556	25	200	50	F	11	Pine	D	L1
14	4	29.0	31.3	10.2	604	15	210	20	R	3	Kan	S	L1
15	4	28.5	39.1	9.8	653	10	200	70	F	3	Kan	M	L1
16	4	22.5	28.1	8.0	702	15	190	80	F	3	Kan	S	L1
17	4	7.3	8.8.	2.1	751	10	190	180	F	4	Kan	D	L1
18	2	2		0.2	800	15	180	220	F	5	Kan	S	L2
19					844	25	170	230	F	10	P/B		P/B
	54												

APPENDIX 4.2

Plot Sheet Summary

Transect 2

16.2.78

Bearing 205°

PLOT	NO. TREES	MEAN AGE	MEAN DBH	MEAN HT	HORZ S	SLOPE	ALT	ASPECT	PHY-SIO	CANOPY HT	DOM. SP.	PINE DENSITY	VEG. TYPE
1					0	5	0	40	T	10	SH		L2
2	4	53	70.2	18.3	41	35	50	45	F	19	Pine	D	L2
3	4	52.5	65.3	17	84	30	80	35	F	17	Pine	D	L2
4	4	53	69.3	17.8	127	30	100	30	F	10	Ka	M	L2
5	4	47	55.3	13.5	172	25	120	20	F	10	Ka	M	L2
6	4	40	57.7	13.8	221	15	150	150	R	14	Pine	M	L2
7					268	20	120	50	G	6	Ka		L2
8	4	34.7	40.0	13	309	35	150	0	F	4	Ka	M	L1
9	4	33.0	36.1	11.5	356	20	170	0	F	3	Ka	M	L1
10	4	22.8	28.3	8.3	403	20	190	105	F	3	Ka	S	L1
11	4	15.5	16.7	5.8	450	20	200	85	F	4	Ka	S	L1
12	4	5.0	4.2	1.4	499	10	225	140	F	4	Ka	S	L1
13					544	25	200	90	G	8	SH/ PB		P/B
	40												

APPENDIX 4.3

Transect 3 — Plot Sheet Summary — 15.2.78

Bearing 205°

PLOT	NO. TREES	MEAN AGE	MEAN DBH	MEAN HT	CUMM DISTANCE (m)	SLOPE	ALT	ASPECT	PHY-SIO	CANOPY HT	DOM. SP.	PINE DENSITY	VEG TYPE
1					0	0	0	15	T	14	Ka/ SH		L2
2	4	56	67.1	18	41	35	50	50	F	18.20	Pine	D	L2
3					84.3	30	40	10	S	12	SH		L2
4	4	51.5	62.8	17	129.6	25	100	25	F	16	Pine	D	L2
5	4	40.5	56.1	14	172.9	30	150	15	F	12	Kan	M	L2
6	4	35.3	47.1	12.5	221.2	15	200	125	F	6	Kan	M	L2
7	4	32.3	36.6	12	270.9	12	200	100	G	8	Kan	M	L2
8	4	29.3	35.1	10.3	317.4	20	225	10	F	6	Kan	M	L2
9	4	26.75	33.1	9	364.4	20	250	45	F	3	Kan	M	L1
10	4	27.5	35.8	8.3	411.4	20	275	45	F	3	Kan	M	L1
11	4	25.25	28.7	7	456.7	25	290	90	F	2	Kan	S	L1
12	4	17.75	21.0	6.1	506.7	5°	300	10	T	1.5	K/m	S	L1
13	4	7.25	9.8	2.3	555.9	10	290	225	F	1.5	K/m	S	L1
14					602.9	20	260	200	F	4	K		L1
15					649.9	20	240	220	F	13	S.H.		P/B
	44												

APPENDIX 4.4

Plot Sheet Summary

Transect 4

Bearing 205°

14.2.78

PLOT	NO TREES	MEAN AGE	MEAN DBH	MEAN HT	HORZ S	SLOPE	ALT	ASPECT	PHY-SIO	CANOPY HT	DOM SP.	PINE DENSITY	VEG TYPE
1	1	55	70.3	18	0	0	0	0	T	12	SH/ Kan	M	L2
2	4	58	51.7	16	41	35	20	55	F	18	Pine	D	L2
3	4	53	50.2	15	86.3	25	80	45	F	14	Pine	D	L2
4	4	45	56.6	16.5	133.3	20	110	65	F	12	Kan	D	L2
5	4	33	45.2	12.5	180.3	20	140	35	F/R	6	Kan	M	L2
6	4	28.5	34.5	11	223.6	30	180	16	R	10	Pine	D	L2
7	4	28.3	30.6	10.5	271.9	15	250	33	F	4	Kan	S	L2
8	4	20.5	22.1	8	321.1	10	275	35	T	4	Kan	M	L2
9					369.4	15	250	65	G	12	SH		P/B
10	4	22.75	24.2	9	416.4	20	180	5	F	3	Kan	M	L1
11	4	22.3	28.5	7.5	464.7	15	290	25	T	3	Kan	S	L1
12	4	7	8.2	3.0	513.9	10	300	300	T	3	Kan	S	L1
13					562.2	15	280	240	F	4	Kan		L1
14					609.2	20	260	260	F	10	SH		P/B
	41												

APPENDIX 4.5

Plot Sheet Summary

Transect 5

Bearing 260°

18.2.78

PLOT	NO. TREES	MEAN AGE	MEAN DBH	MEAN HT	HORZ S	SLOPE	ALT	ASPECT	PHY-SIO	CANOPY HT	DOM SP.	PINE DENSITY	VEG TYPE
1	1	61	84.0	18.2	0	0	Om	30	T	9	Kan	S	L2
2	4	54.8	70.5	15.8	45.3	25	20	30	F	10 18	Kan	M	L2
3	3	59.7	72.3	18.3	88.6	30	30	50	F	8 17	kan pine	M	L2
4	4	51.8	60.6	17.8	133.9	25	50	60	F/R	8	kan	M	L2
5	4	40.8	40.2	11.5	179.2	25	70	30	F/R	4	kan	S	L1
6	4,	7.8	5.0	9.0	224.5	25	90	30	F	3	kan	S	L1
7					267.8	30	100	40	F	8	SH/ PB		PB
	20												

APPENDIX 5.1

PINASTER AGE/HEIGHT RELATIONSHIPS

To determine the true or actual age of pines sampled at the standard 25cm sampling height, and also to make an allowance for trees sampled higher than 25cm, a simple age/height relationship was required. In the literature available there was very little information on such a relationship and Weston (1957) only states that growth in P. pinaster is slow initially but then increases to about 30-40 cm/year and then gradually increases faster than this depending on site. It was thought necessary then to derive a rough age/height relationship by cutting a number of small pines and sectioning them at 5cm intervals for ring counts.

A rough relationship determined from sectioning thirty trees was found as follows:

Height (cm)	Age (years)
25	2-3
40	3
70	4
100	5
140	6

Table 1: Age/Height Relation in Maritime Pine

N.B. These are also graphed in Appendix 5.2 to aid extrapolations.

1. True Ages

Where required the ages for the given sampling height in Table 1 were added to the relative tree age (i.e. the age derived from increment boring at the 25cm standard height).

e.g. Tree	Ages	Sampling Height
3	25-26	25

The true age becomes 25 years (the lowest ring count + 3 years = 28 years.

SAMPLING HEIGHT (cm)	30	40	50	60	70	80	90	100
RELATIVE AGE DIFFERENCE (yrs)	0	1	1	1	2	2	2	3

Table 2: Relative Age Relationship

2. Relative Ages

in determining the relative age of trees sampled other than 25cm, the difference between the 25cm age and the actual sampled height age on the tree, (Table 2) was added to the age determined from the ring count.

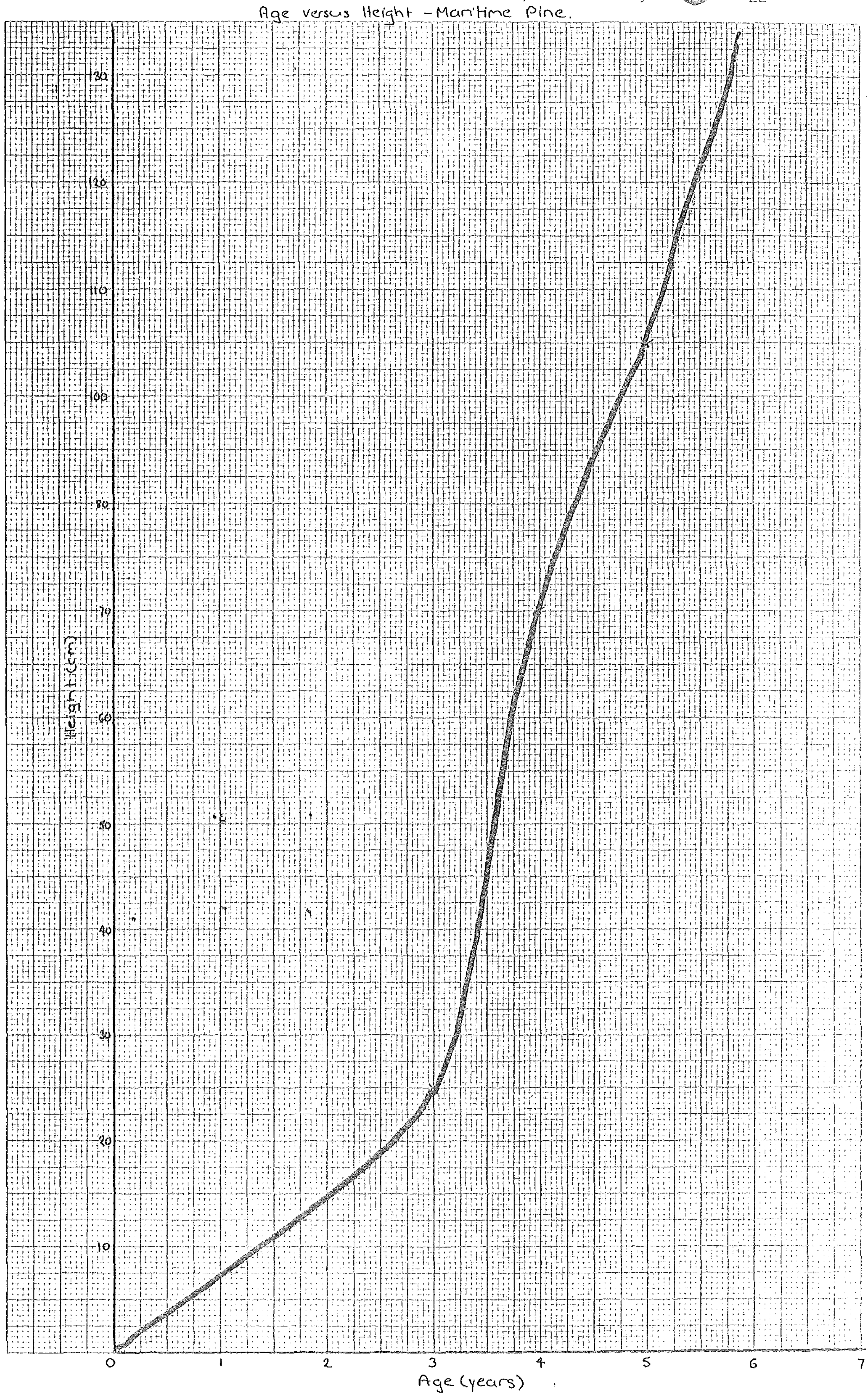
e.g.	Tree	Ages	Sampling Height
	2	25-26	80

The relative age (i.e. relative to other trees sampled at 25cm height) becomes 25 years + (5 years - 3 years) = 27 years OR using Table 1: 25 years + 2 years = 27 years.

As such this is a rough guide only and implies no accuracy but is useful for extrapolating back to relative or true ages where this is necessary (e.g. determining the age of the oldest tree planted at Bark Bay.

APPENDIX 5.2

AGE/HEIGHT GRAPH



APPENDIX 6.1

DATA ANALYSIS

1. Sampling for Age

It should be remembered that when each plot was sampled it was the four largest trees, most representative of the surrounding vegetation that were sampled. This was designed to favour the older trees on each plot so that an approximate rate of spread could be calculated. For each plot then, upon which pine occurred, the mean oldest age, DBH and height were calculated from data recorded on Increment Core Data Sheet I (Appendix 3.1). A breakdown of these data for each of the five transects are contained on the plot sheet summaries in Appendices 4.1 - 4.5.

The analysis of ages was done in relative ages throughout (i.e. the 25cm sampling point age) and where trees less than 2m in height were encountered and cut, their 25cm age was recorded to maintain consistency with increment cored trees. For trees sampled at a height greater than the standard 25cm sampling height, the age/height relationships in Appendix 5.1 were used to estimate a relative age consistent with the 25cm sampling position. With respect to the recording of two ages for each tree, the lowest age value was taken as most correct for tabulation purposes. This was for reasons of the supposed incidence of false growth rings in pinaster (Scott, 1962).

Each of the distances between plots was interpreted as a true horizontal distance by taking account of the slope between successive plots:

i.e. True Horizontal Distance = AD x COS Ø

AD = actual distance between plots

Ø = average slope of land back to the previous plot.

With regard to plotting distance against age, height and DBH, the base line for the transects was located away to the S.W. of the group of trees assumed to be the initial seed source. To account for this, a distance of 50m was added to each of the true horizontal distances to give a true representation of horizontal distance from seed source. The exceptions here are Appendices 4.1 - 4.5. The mean DBH, height and age 70 years calculated in Appendix 1.3 were used for the 0 metre distance in all cases, being the mean sizes and age of the assumed initial seed source.

2. Rate of Spread

In calculating rate of spread of pinaster two basic assumptions were made:

i) that the "Homestead Flat" at Bark Bay was the centre of origin of pinaster seed within the Park

ii) that the oldest tree on the Flat was 70 years old (Appendix 1.3).

The rates of spread (metres/year) as tabulated in Appendices 6.2 - 6.4 were determined using the following formulae:

$$\text{Rate of spread (m/yr)} = \frac{CHD}{70 - A}$$

CHD - Cumulative horizontal distance from initial seed source to the plot

A - Mean oldest tree age at that plot

70 - Age of assumed initial seed source at distance 0m.

This gave a rate of spread for each plot away from the assumed initial seed source. These rates of spread are tabulated for each transect in Appendices 6.2 - 6.3 and to get the mean rate of spread for the transect(s) these rates of spread were averaged (e.g. Appendix 6.3).

3. Graphical Analysis

For each transect mean DBH, height and age of the trees on each plot were graphed against true horizontal distance, (Appendices 7.1 - 7.5) and for transects 2, 3 and 4 a histogram was constructed to illustrate the relation of age on distance (Fig. 2).

4.1 Site Variables

A summary of site variables for all transects was tabulated from the increment core data sheets and is shown in Appendices 4.1 - 4.5.

APPENDIX 6.2

Transect Rates Of Spread

Transect 1

Plot Dist. + 50m	Age	Rate of Spread (m/yr)
50		
91	56	6.5
132	54	8.25
177		
223	42	6.32
271	41	7.69
320	28	7.62
368	26	8.36
417		
466	3	6.96
515		
560	29	13.66
60	30	15.15
654	29	15.95
703	29	17.15
752	23	16.0
801	7	12.71
850	2	12.5
894		

Mean Rate of Spread =

$$\frac{154.82}{14}$$

= 11.059 m/yr

Transect 5

Plot Dist. + 50m	Age	Rate of Spread (m/yr)
50	61	5.56
95	55	6.33
139	60	13.90
184	52	10.22
229	41	7.897
275	8	4.44
318		

Mean Rate of Spread =

$$\frac{48.347}{6}$$

= 8.058m/yr

APPENDIX 6.3

Transect Rates of Spread

Transect 2			Transect 3			Transect 4			Mean Rate of Spread (m/yr)
Dist.	Age	Spread	Dist	Age	Spread	Dist	Age	Spread	
50			50			50	55	3.33	3.33
91	53	5.35	91	56	6.5	91	58	7.58	6.48
134	53	7.88	134			136	53	8.0	7.94
178	53	10.47	180	52	10.0	183	45	7.32	9.26
223	47	9.70	223	41	7.69	230	33	6.22	7.87
271	40	9.03	271	35	7.74	274	29	6.683	7.82
318			320	32	8.42	322	28	7.67	8.05
359	35	10.26	367	29	8.95	371	21	7.57	8.91
406	37	12.30	414	27	9.63	419			7.31
453	23	9.64	461	28	10.98	466	23	9.92	10.18
500	16	9.26	507	25	11.27	515	22	10.73	10.42
550	5	8.46	557	18	10.71	564	7	8.95	9.37
595			606	7	9.62	612			9.62
			653			659			
			700						

Mean Rate of Spread $= \frac{83.975}{11}$ $=$ 7.634m/yr.

Mean Rate of Spread $= \frac{101.51}{11}$ $=$ 9.228 m/yr

Mean Rate of Spread $= \frac{92.352}{10}$ $=$ 9.235m/yr

Total Mean Rate of Spread $= \frac{26.097}{3}$

$=$ 8.699 m/yr

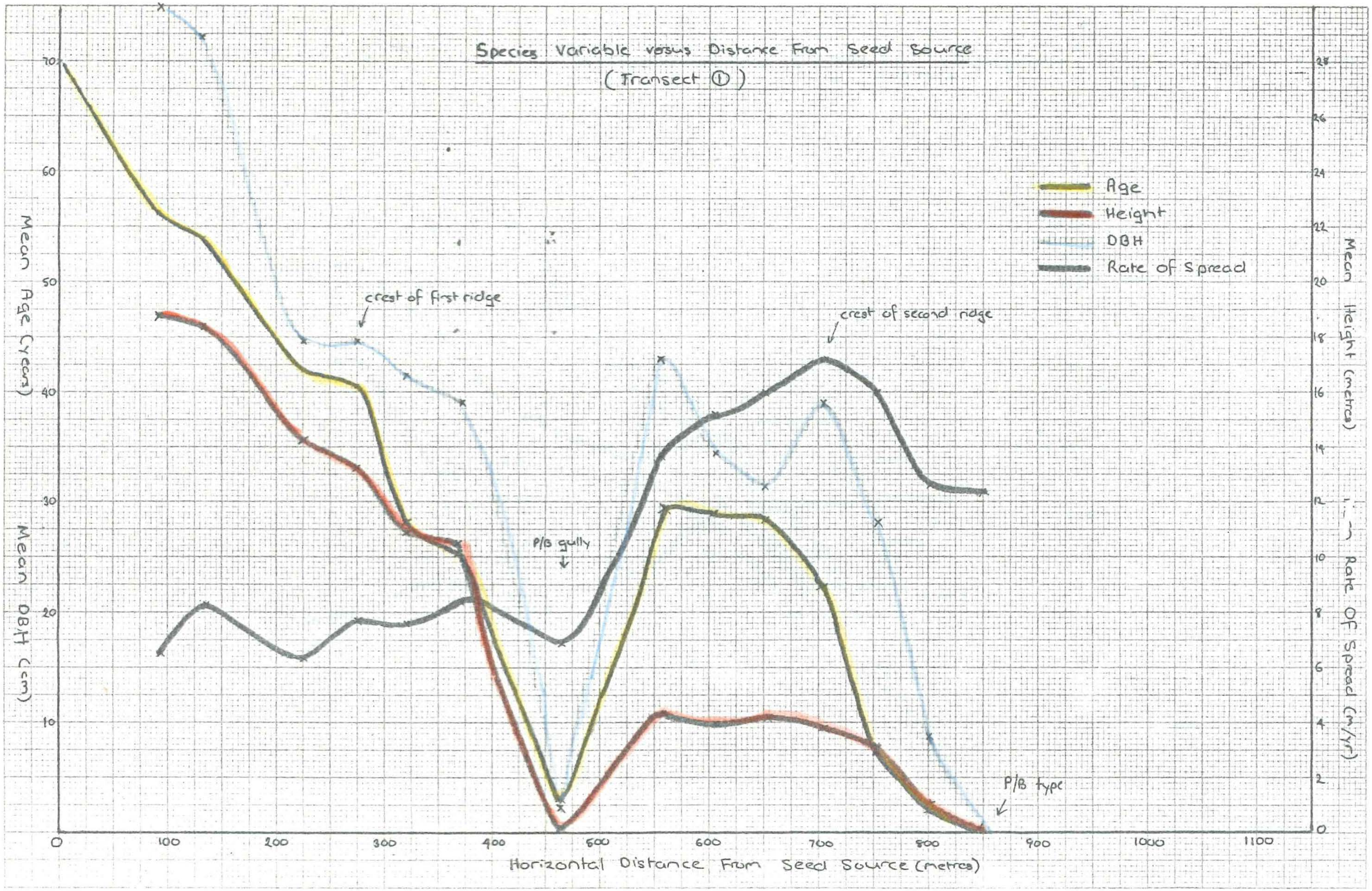
APPENDIX 6.4

Mean Rate of Spread - Transects 2, 3, 4

Cum. Dist + 50m	Mean Height (m)				Mean D.B.H. (cm)				Mean Age
	2	3	4	Av.	2	3	4	Av.	
0				18.2				88.74	70
0-50			18	18.0			70.3	70.3	55
50-100	18.3	18	16	17.43	70.2	67.1	51.7	63	56
100-150	17		15	16.0	65.3		50.2	57.75	53
150-200	17.8	17	16.5	17.10	69.3	62.8	56.6	62.9	50
200-250	13.5	14	12.5	13.33	55.3	56.1	45.2	52.2	40.3
250-300	13.8	12.5	11	12.43	57.7	47.1	34.5	46.43	34.67
300-350		12	10.5	11.25		30.6	30.6	33.6	30
350-400	13	10.3	8	10.43	40	35.1	22.1	32.4	28.3
400-450	11.5	9		10.25	36.1	33.1		34.6	32
450-500	8.3	8.3	9	8.53	28.3	35.8	24.2	29.43	24.67
500-550	5.8	7	7.5	6.77	16.7	28.7	28.5	24.63	21
550-600	1.4	6.1	3.0	3.50	4.2	21.0	8.2	11.13	10
600-650		2.3		2.30		9.8		9.8	7
650-700									
700-750									

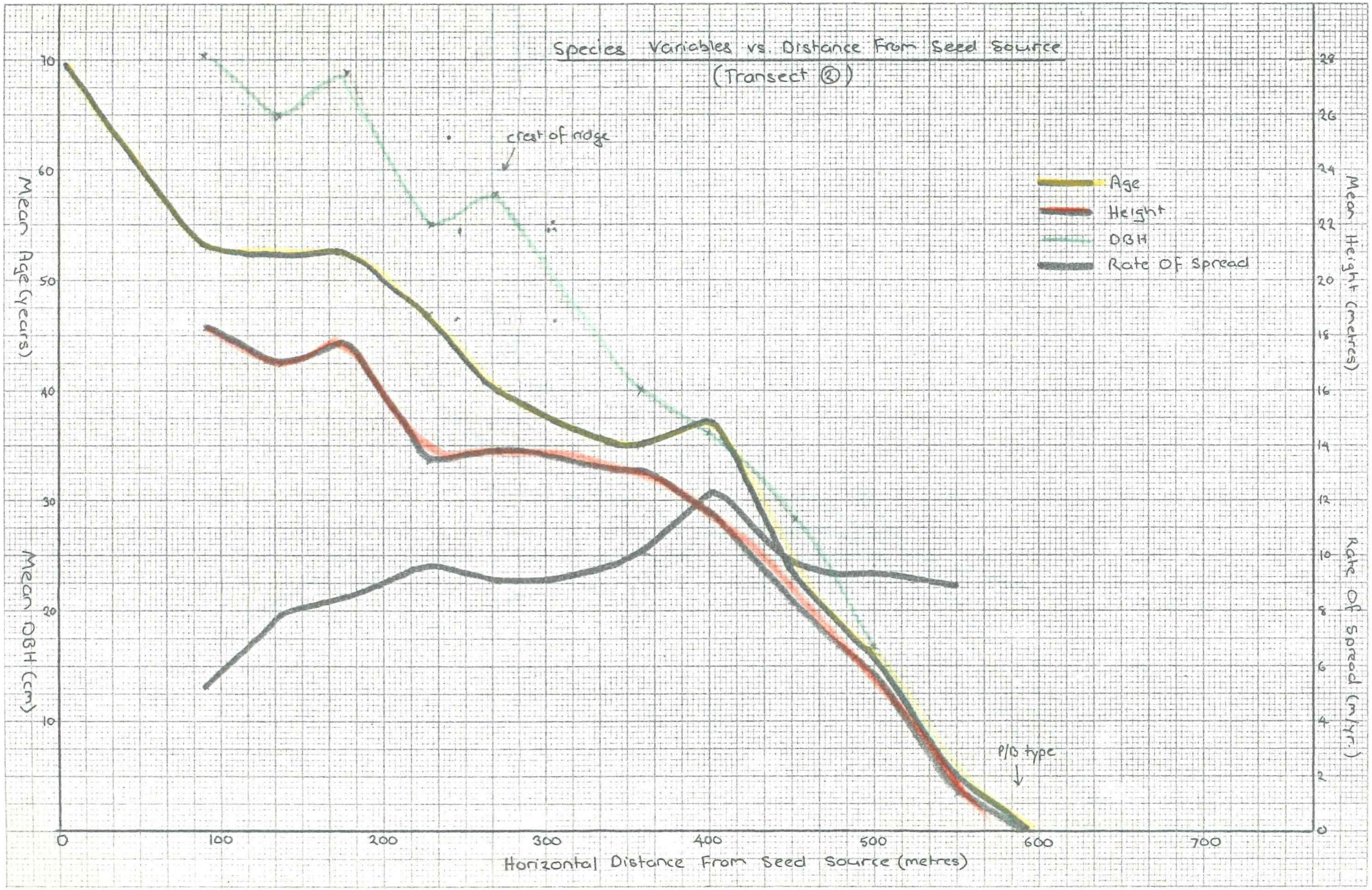
APPENDIX 7.1

GRAPHICAL REPRESENTATION - TRANSECT 1



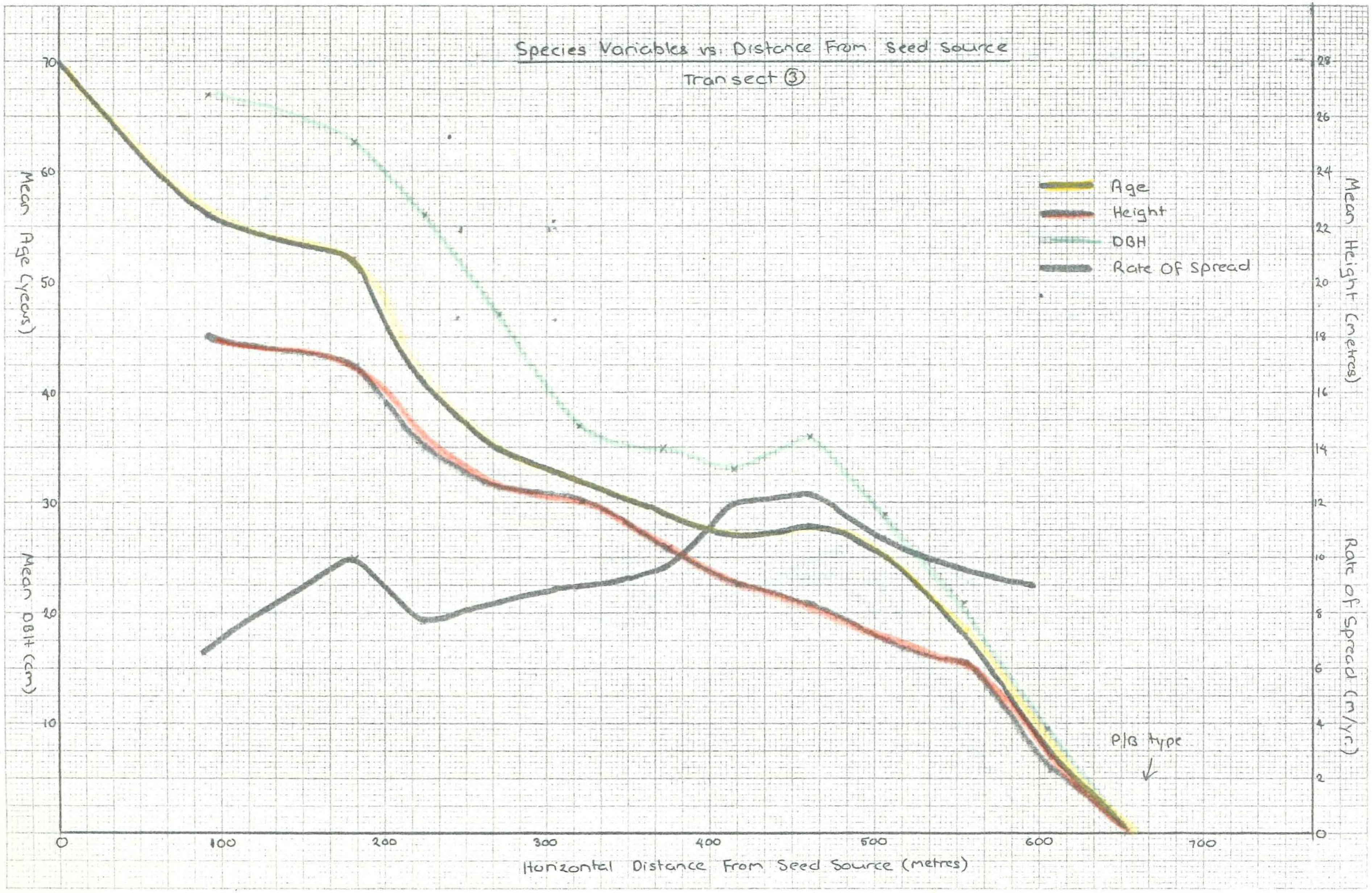
APPENDIX 7.2

GRAPHICAL REPRESENTATION - TRANSECT 2



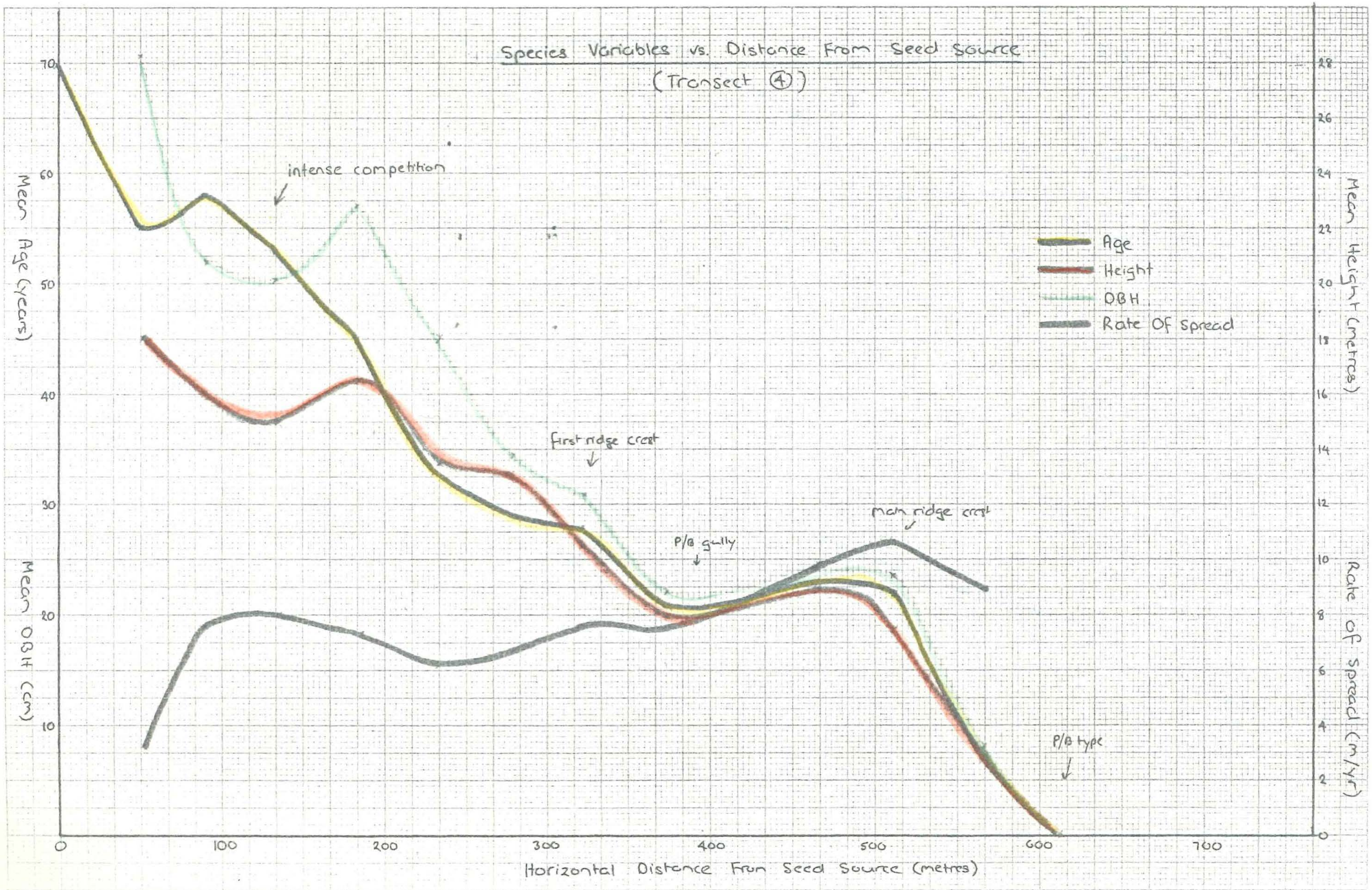
APPENDIX 7.3

GRAPHICAL REPRESENTATION - TRANSECT 3



APPENDIX 7.4

GRAPHICAL REPRESENTATION - TRANSECT 4



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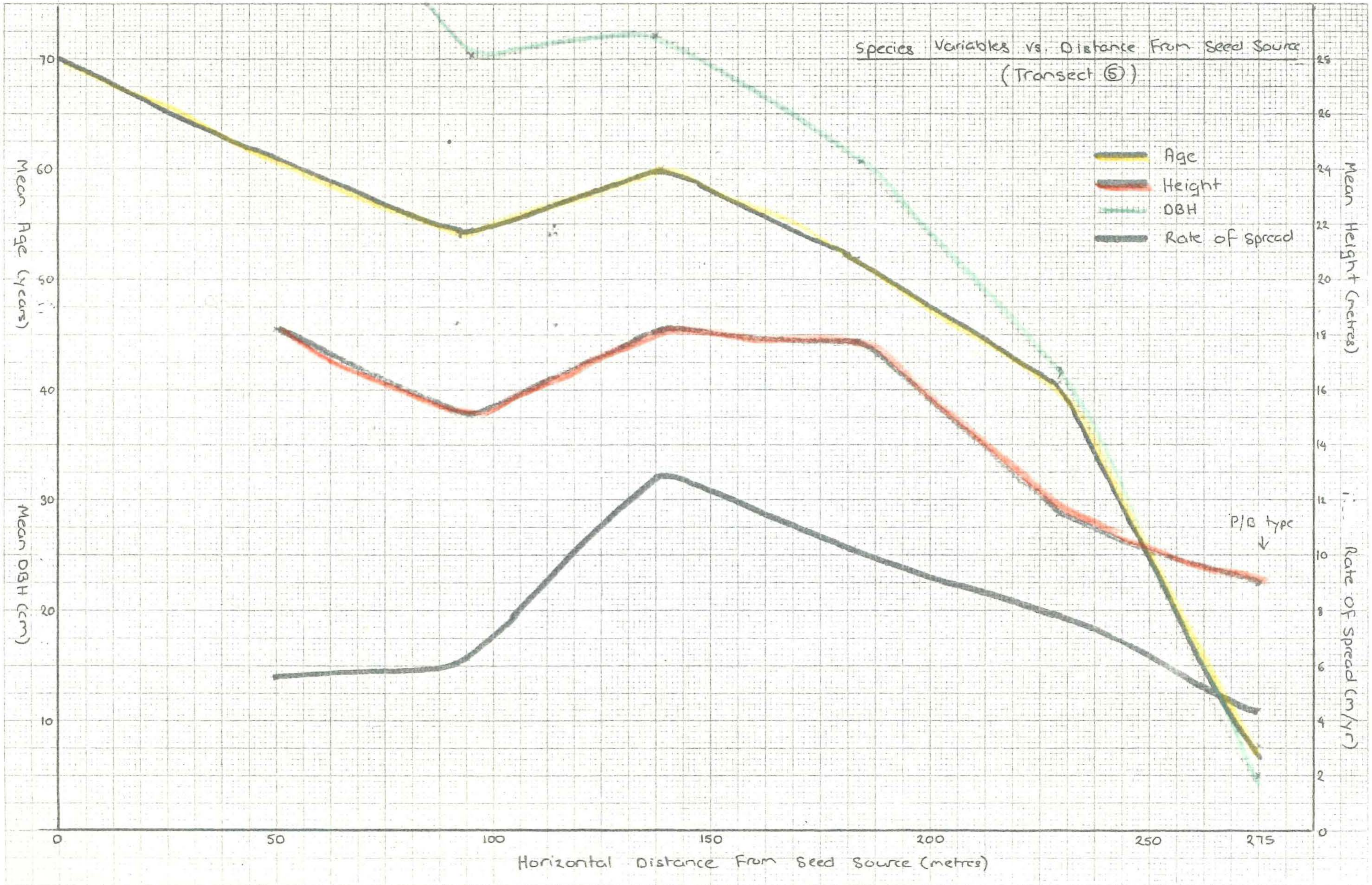
APPENDIX 7.5

GRAPHICAL REPRESENTATION - TRANSECT 5



APPENDIX 8.1

GLOSSARY OF PLANT NAMES USED IN TEXT

1. Exotic

bracken	*Pteridium aquilinum var. esculentum*
gorse	*Ulex europaeus*
hakea	*Hakea acicularis*
	Hakea saligna
Japanese Cedar	*Cryptomeria japonica* (L.f.) D. Don
maritime pine	*Pinus pinaster* Aiton
radiata pine	*Pinus radiata* D. Don

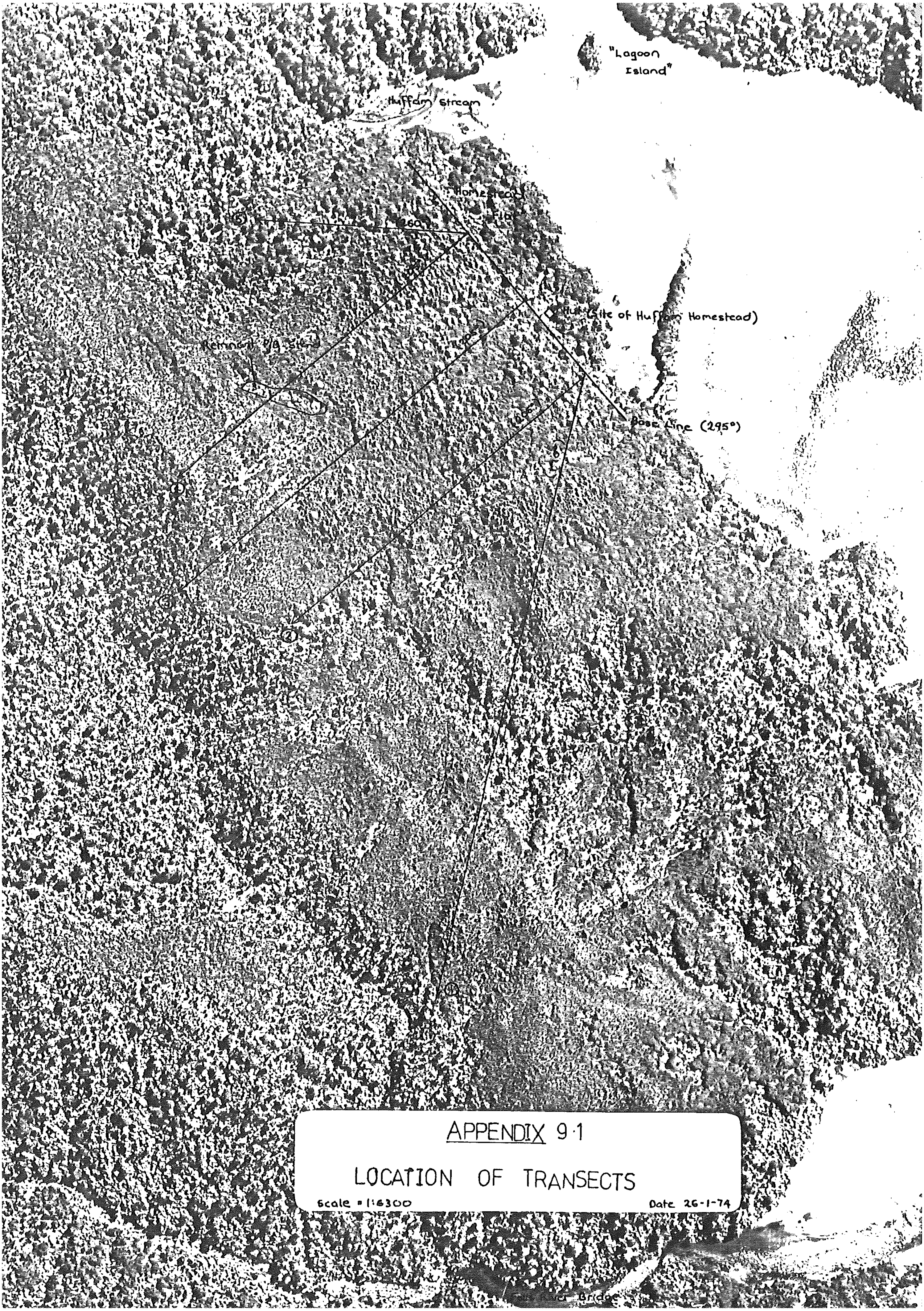
2. Indigenous

ake-ake	*Dodonea viscasa*
black beech	*Nothofagus solandri* (Hook.f.) Oerst var. *solandri*
broadleaf	*Griselinia littoralis* Raoul
Halls totara	*Podocarpus hallii* kirk
hard beech	*Nothofagus truncata* (Col.) Ckn
hinau	*Elaeocarpus dentatus* (J.R. et G.Forst.)Vahl
kamahi	*Weinmmania racemosa* Linn.f.
kanuka	*Leptospermum ericoides* A. Rich.
mahoe	*Melicytus ramiflorus* J.R. et G. Forst.
manuka	*Leptospermum scoparium* J.R. et G. Forst
matai	*Podocarpus spicatus* R. Br. ex Mirbel
miro	*Podocarpus furrugineus* G. Benn. ex D.Don
nikau	*Rhopalostylis sapida* Wendl.et Drude in Kerch
pigeonwood	*Pittosporum eugenoides*
rata	*Meterosideros umbellata*
red beech	*Nothogagus fusca* (Hook.f.) Oerst
rimu	*Dacrydium cupressinum* Lamb.
silver beech	*Nothofagus menziesii* (Hook.f.) Oerst.
totara	*Podocarpus totara* G. Benn ex D. Don
tree ferns	*Cyathea, Dicksonia*

Reference:

Allan, H.H., 1961: *Flora of New Zealand Vol.1* Govt. Printer, Wgtn.

Dallimore, W. & A.B. Jackson, 1966: *A Handbook of Coniferae and Ginkgoaceae*, Arnold, London



APPENDIX 9·1

LOCATION OF TRANSECTS

Scale = 1:6300 Date 26-1-74